Transactions of
American Society
for Steel Treating

SPECIAL FEATURES

Of
pyror
this p
certai
ings.
time

Reg
neces
carefu
as to
from
with
plants
insura

Rea
of th
tative
Large
check
metal
stock
These
pyror
burea

Un
in its
ing C
cuse,
need
habit
ductio
passe
clean

Th
probl
only
ing w

WATCHING THE WATCH DOG

Of all the auxiliary equipment utilized in heat treating operations, the pyrometer perhaps is the most important. Whether manual or automatic, this piece of apparatus serves as the watch dog of furnace temperatures, certain cycles of treatment being governed almost entirely by its readings. All conditions being equal, uniform results in product are obtained time and time again through the faithful service of these instruments.

Regardless of the type and operating principle, these devices are necessarily delicate and may become inaccurate in spite of the most careful handling and manipulation, their falsity sometimes being so slight as to remain undetected until the product fails in test. Much trouble from this source can be minimized by periodic checking of pyrometers with instruments either standard or known to be correct. For the smaller plants such a policy may have disadvantages, however, it is reasonable insurance against lowering the standard of product.

Realizing the importance of pyrometer equipment, some manufacturers of this equipment have instituted a service whereby traveling representatives of the company inspect and check the apparatus at given intervals. Larger plants which use a number of pyrometers frequently prefer to check their own instruments, and for this purpose, the department of metallurgy, United States bureau of standards, Washington, carries in stock pure specimens of various metals having known thermal properties. These metals are made and sold expressly for the purpose of checking pyrometers when time does not permit sending the instruments to the bureau. Either of the two methods produces desired results.

COMBATTING INDUSTRIAL WASTE

Undertaking of a survey on industrial waste and the proper methods in its elimination were announced at the recent meeting of the Engineering Council of the Federated American Engineering Societies in Syracuse, N. Y. Although still a young organization, the society feels the need of all engineers joining hands in purging industry of extravagant habits and methods which gained a foothold when during the war production was demanded at any price. The day for those methods is passed for the present business depression is effecting its own house cleaning—the present demand of industry is economy.

The Federated American Engineering Societies has chosen a huge problem as its first achievement and one in which it has the support, not only of manufacturers but of the public. Conditions are ripe for attacking waste in a whole-hearted and determined way. As evidencing the

FIG. 1—MANUFACTURERS BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE 1921 CONVENTION WILL BE HELD SEPT. 19-24. FIG. 2—INTERIOR OF SAME BUILDING SHOWING 25,000 OF THE 78,000 SQUARE FEET OF EXHIBITION SPACE. FIG. 3—WOMAN'S BUILDING WHERE SESSIONS WILL BE HELD. IT IS 400 FEET FROM EXHIBITION HALL

1921

sincerit
already
its repo
to be f
welfare

The
executi
to fill th
Th
Pre
On
Tre
On
Me
dations
Chalme

Th
Studeba
Mass.;
U. Sco

INDIA

Th
tion ar
the we

Be
to the
which
ciently

Inc
the Ma
total fl
this bu
Garden
The bu
purpose
20-foot
the liv
arrange
electric
buildin
March

Th
400 fee
more la
meeting

Th
ing con
the ent
George

sincerity with which the movement has been started, the organization already has a committee making a national survey of conditions and upon its report and recommendations to the Council will depend the procedure to be followed in the assay. In the interest of industry and the nation's welfare, most hearty indorsement is given to the new movement.

NOMINATING COMMITTEE TO MEET

The Nominating Committee of the Society will hold a meeting in the executive offices in Cleveland on Friday, March 25, to nominate officers to fill the vacancies for the year 1921-1922.

The offices for which nominations are to be made are as follows:
President.
One Vice President.
Treasurer.
One Member of Board of Directors.

Members of the Society are requested and urged to send recommendations to the chairman of this committee, J. Fletcher Harper, Allis Chalmers Co., Milwaukee, Wis.

The other members of the nominating committee are: H. G. Kiefer, Studebaker Corp., Detroit; A. E. Bellis, Springfield Armory, Springfield, Mass.; A. W. F. Green, John Illingsworth Steel Co., Philadelphia, and C. U. Scott, C. U. Scott & Son, Rock Island, Ill.

INDIANAPOLIS WINS 1921 CONVENTION AND EXHIBITION

The Board of Directors has decided to hold the third annual convention and exhibition of the American Society for Steel Treating during the week of Sept. 19 to 24 inclusive, at Indianapolis.

Before arriving at this decision the Board gave serious consideration to the many invitations received. Because of the enormous size to which the exhibition has grown, there are very few cities having a sufficiently large building capable of accommodating the exhibition.

Indianapolis was fortunate in having on the State Fair Grounds, the Manufacturers' Building, 360 feet in length by 220 feet in width, the total floor area of which is 78,000 square feet. The central section of this building measuring 240 feet x 100 feet, is known as the "Sunken Garden", and is 20 inches below the level of the surrounding floor space. The building is new, well lighted, and excellently adapted for exhibition purposes. The management has divided the floor space into 161 10 x 20-foot sections. The booths along the north wall are to be used for the live exhibits and are supplied with gas and compressed air, while arrangements also have been made for the exhibitors requiring heavy electrical current to locate on the promenade on the same side of the building. The floor plan probably will be ready for distribution by March 15, when reservations can be made.

The meetings are to be held in the Women's Building, located about 400 feet from the exhibition hall, where there will be available three or more large meeting rooms where it will be possible for several sectional meetings to be held simultaneously.

The Indianapolis chapter of the Society is engaged actively in making comprehensive plans for successfully carrying on its part in making the entertainment of the visiting members and guests a notable occasion. George Desautels, national member of the Program and Papers Commit-

tee, is organizing the members of the chapters into 15 committees, not the least of which is the one devoted to the entertainment of delegates and their wives. The Indianapolis chapter plans to raise $5000 for entertainment purposes, and expects to show the visitors a very enjoyable time.

The requests that have been coming into the National office at 4600 Prospect avenue, Cleveland, for information as to reservations and floor plans, indicate that the exhibition this year will be larger than it was at Philadelphia last year, and all indications point to an attendance of at least 15,000 people.

A DISCUSSION OF MOLYBDENUM STEELS
By Charles McKnight*
(A Paper Presented Before the Pittsburgh Chapter)

Molybdenum steels were first brought into use in answer to the exacting demands of the war. They served their purpose admirably but in the reaction which followed the war they fell into disfavor, perhaps because the steel users "fear the steelmakers even bearing gifts", perhaps because one or two bad heats of molybdenum steel were allowed to get out and fell down in service. Whatever the reason, a counter-reaction now is going on and these steels are receiving an almost enthusiastic reception, especially from automobile manufacturers.

The first use of molybdenum in alloy steels was probably in high speed tool steel either to replace or to augment the effect of tungsten. In this connection, a report on the efficiency of tool steels presented before the British Iron and Steel institute in 1919 by Messrs. Arnold and Ibbotson shows that a chrome-molybdenum-vanadium steel containing 5.79 per cent molybdenum removed more metal in a machining test than did a chrome-tungsten-vanadium steel containing 15.93 per cent tungsten and otherwise practically identical with the first steel. It would appear from this that one part of molybdenum produced substantially the same results as 2.7 parts of tungsten.

These experiments, however, had little to do with the development of the socalled commercial molybdenum steels, referring to steels containing less than one per cent of molybdenum which can compete on a cost basis with other structural alloy steels. It appears that the first extensive experimentation along these lines with a broad enough scope to be of really great value was undertaken by Messrs. Wills and Chandler at the Ford Motor Co. factory. At this time the Ford car was built for the most part of steel which was ordered to conform to the analysis: Carbon, 0.23-0.28 per cent; chromium, 1.00 per cent; vanadium, 0.18 per cent; and manganese, 0.70-0.90 per cent.

This analysis was so written that the steelmaker would average 7 per cent of his heats on the low side and 15 per cent on the high side as far as carbon is concerned. The low carbon heats were used for case hardened parts and the high carbon ones for the oil quenching parts. Thus this one specification covers all parts of the car except specialties, such as balls for ball-bearings and magnet steel for the magneto.

On account of the monopoly on vanadium and the royalty on its use a search was made for a steel which would replace the chrome-vanadium for universal use in an automobile—that is, for one which, coming low in

---

*President, the Carbon Steel Co., Pittsburgh.

carbons, could be used for case hardening, coming high could be used for oil quenching, and within the range would be suitable for the structural parts of the car. There is no such steel available. For example, to replace chrome-vanadium with a straight chrome steel of the same physical properties it would be necessary to raise the carbon to a range, say of 0.25 to 0.35 per cent and the chrome up to 1.10 to 1.25 per cent and in so doing the purpose of the universal steel is defeated.

Therefore, a systematic and logical search of the periodic system was undertaken to find if possible the element or elements which added to steel would furnish an alloy fulfilling all the specifications. Such an ideal alloy steel, to quote the metallurgist of one of our largest automobile manufacturers, would have to show the following characteristics.

The alloying element used in its manufacture must be readily obtainable and the supply practically inexhaustible. It also must be capable of developing readily at least our present minimum physical properties and preferably something better. It must not be subject to monopoly or patent litigation. It must be so produced at the mill that its percentage of rejections due to seams, segregation and pipes is under 2 per cent of the finished bar. It must forge readily and flow easily at a temperature of 2100 to 2550 degrees Fahr., thus reducing the percentage of forgings which are thrown out for not filling out the dies and other forging defects. It must have a wide heat treatment range and must be as fool proof as possible in order to eliminate the necessity for elaborate control to produce well heat treated forgings. It must possess the quality of easy and uniform machineability with no diminution of our present physical properties. It must lend itself to the water quench.

Pursuing this quest, one element after another was tried. Some met most of the specifications, some a few and some were totally unsuited. To mention a few, iridium was cast into the discard on account of its rarity, as were rhodium, platinum and other rare metals. Uranium unfortunately at that time was too uncertain in supply and too costly; zirconium, which gave some remarkable results, was too erratic in its action, at times going into solution and at other times exercising its affinity for oxygen with detrimental effects.

Finally the choice fell on a chrome-molybdenum steel. The supply of chromium is practically inexhaustible and is found in all parts of the world, while four-fifths of the world's known supply of molybdenum is contained in the United States. On the other hand, most of our nickel comes from Canada and practically all of our vanadium is imported from Peru. There was no patent litigation and arrangements have been made to prevent any in the future. This steel will forge readily, has a wide heat treatment range and possesses exceptional machining qualities, as will be shown later, and there are no unusual difficulties attached to its manufacture.

When the decision was finally made that a molybdenum steel most nearly fulfilled all the specifications for the ideal steel, its manufacture was begun. This was, as nearly as can be ascertained from the incomplete records, the introduction of molybdenum steels into the commercial, structural field.

The manufacture of molybdenum steels is no more intricate than that of any other alloy steel. The metal is supplied in two forms, either as ferromolybdenum, which contains 50 to 60 per cent of molybdenum, or as calcium molybdate, the purer form, which contains 42 per cent, the

balance being lime. The steel may be made by the crucible, electric, or open-hearth processes and the producers of the alloy state that it may be added to the charge in three ways. First, the ferro can be introduced into the bath just before the charge is completely melted and the lime has begun to come up; second, it may be added before tapping at the same time as the ferromanganese and third, it may be added in the ladle. This last named method should be avoided when possible as the liability of imperfect distribution and segregation is great. In our practice, the ferro addition is made at any time after the slag is in shape, allowing ample time for its dissemination throughout the bath.

The use of calcium molybdate, naturally, is less common but its employment is about the same, the containers being thrown into the bath through the slag. It cannot, of course, be added in the ladle. In the electric furnace the molybdate is added after the first slag has been skimmed.

No especial precautions should be taken in either pouring or rolling, except those which would be taken with any alloy steel, and it usually will be found that the percentage of product will be greater and the rejections for seams, segregation or piping less with molybdenum steel than with corresponding grades of alloy steels. This is particularly noticeable when a chrome-molybdenum steel is compared with a nickel-chrome.

At present, the use of molybdenum in quantities under 1 per cent as an alloy is covered by analyses which include straight molybdenum, chrome-molybdenum, nickel-molybdenum, nickel-chrome-molybdenum and chrome-vanadium-molybdenum steels.

The effect of the molybdenum addition in these steels is marked. The tensile properties of the steel are raised above those of a steel of similar analysis but without the molybdenum and the elastic ratio is higher. But the most impressive effect is that of raising the reduction of area with a corresponding increase in the toughness. This can best be shown by a comparison of some actual physical results as follows:

	Chrome Nickel		Chrome Molybdenum	
	per cent	per cent	per cent	per cent
Carbon	0.28	0.37	0.23	0.30
Manganese	0.30	0.70	0.50	0.70
Chromium	0.65	1.36	0.74	0.98
Nickel	3.04	3.50	2.58	3.05
Molybdenum			0.32	0.54

Elastic limit, 116,700 pounds per sq. in.; 130,000 pounds per sq. in.
Ultimate strength, 135,200 pounds per sq. in.; 142,000 pounds per sq. in.
Elongation, 19.6 per cent; 20.5 per cent.
Reduction of area, 57.1 per cent; 65.0 per cent.

In other words, the addition of less than 0.5 per cent molybdenum with lower nickel and slightly lower chrome produced an increase in the elastic limit of 13,000 and in the ultimate tensile strength of 7000 pounds per square inch, at the same time raising the elongation about 1 per cent and the reduction of area about 8 per cent.

But these are not the only advantages. In fact, considering some of the other superiorities, the gain in physical properties becomes simply a matter of interest. Molybdenum steels have demonstrated that they have an extremely wide range for practical heat treatment which is a quality of great value in these days of unskilled and careless labor, for it

means that, instead of controlling the heat treating furnaces within a very narrow range, a difference in quenching temperature of 100 degrees makes little or no change in the properties of the finished steel. This is shown in the following table, which gives the tensile results on a piece of steel containing 0.20 per cent carbon and 0.70 per cent molybdenum when quenched in oil from varying temperature and drawn at 1000 degrees Fahr. Only the grossest negligence could duplicate such a test in shop practice and yet, even if it occurred, there would be little damage done. The results follow:

Quenching Temperature degrees Fahr.	Elastic limit, pounds per square inch	Ultimate strength, pounds per square inch	Elongation per cent	Reduction in area, per cent
1600	90,400	101,600	22.0	64.2
1700	88,440	102,000	22.5	62.9
1800	89,040	103,500	24.0	65.4
1900	88,630	100,600	23.0	64.2
2000	88,800	103,700	22.0	62.3

In addition, molybdenum steel permits a higher drawing temperature in order to obtain the same physical results. For example, in the manufacture of Liberty motor crankshafts from nickel-chrome steel, the permissible drawing range, was from 1050 to 1150 degrees Fahr., but in order to meet the requirements it was sometimes necessary to quench from the drawing temperature while the average drawing temperature on the nickel-chrome-molybdenum shafts was 1150 degrees Fahr. and the physical characteristics were slightly higher than with the other steel.

To appreciate the advantages of this it is only necessary to recall that a piece of quenched steel is in a state of unstable equilibrium and that the higher the drawing temperature the nearer the approach to a state of stable equilibrium in the steel. It is a matter of inference from this point to carry the argument a step further. Fatigue is a molecular disturbance of the metal, therefore, the nearer the steel is to a condition of stable equilibrium, the higher its powers of resisting fatigue and shock. This inferential argument seems to be borne out in the case of molybdenum steels both in laboratory tests and in actual shop practice. There is a decided difference in opinion as to value of impact and fatigue testing machines, thus without arguing as to the value of these, it will be sufficient to say that in almost every case on record, molybdenum steels have had a higher impact value than similar steels without molybdenum. The following table shows the results on Liberty motor crankshafts:

	Elastic limit, pounds per square inch	Elongation per cent	Reduction in area, per cent	Brinell	Impact, foot, pounds
Specifications call for	116,000	16.0	50.0	266	34
Medium chrome-nickel steel	129,760	17.2	53.7	307	46
High chrome-nickel steel	116,700	19.6	57.1	270	61
Molybdenum steel .	130,000	20.5	65.0	303	67

Finally, there are three great benefits to the shop in the use of these steels: forgeability, machineability and uniformity of results. Taking the last first, it is remarkable what small variations appear in extended

working with these steels. There are not so many freak tests and a greater reliance can be placed on results. This quality appears in a different way in the hardening of molybdenum steels. In quenching a large section it is usual to find a variation from the center of the mass to the edges, the hardness becoming more and more progressive. The same results are obtained with molybdenum steels but to a much lesser degree, the center and the edge showing less hardness variation.

As for forgeability, the working range is wider with molybdenum steel than with other steels and it flows better under the dies. The following quotations are from the reports of two different automobile companies. "Chrome-molybdenum steel has a wider heat treating range than chrome-nickel and works better at lower temperature." Again: "It is apparent that chrome-molybdenum has a wider forging range than chrome-nickel. We had one of the oldest and best hammer men in the shop on this job and he was highly pleased with the way the steel worked. A new set of dies was used and the axle was filled out perfectly at all points, which is very unusual with chrome-nickel under the same conditions. There was no scrap in 100 axles forged."

The ability of molybdenum steels to withstand abrasion has been questioned and unfortunately no data on this particular characteristic is available. The only test bearing on the subject is that made by a shovel manufacturer in the course of an investigation preliminary to adapting a molybdenum steel for his product. In this test, which approximated as closely as possible actual service conditions, the shovels were subjected to wear and abrasion equivalent to many months of field work, and although it is impossible to quote the actual result, the molybdenum shovels withstood wear and abrasion equally as well and in most cases better than shovels made from steel of other analysis.

If there is one pre-eminent quality attached to molybdenum which overshadows all the rest of the advantages, it is that of easy machining. It is the condition which enables the higher priced molybdenum steels to compete equally with other alloy steels for, if a steel works well in the shop, it can easily overcome the handicap in price of a steel which is delicate to heat treat, difficult to forge and hard to machine. There is such a mass of evidence bearing out the truth of these claims that it is difficult to make a choice for quotation, but following are examples.

A manufacturer of automobile parts in comparing chrome-molybdenum with chrome-nickel and 3.5 per cent nickel steels in a shop test found that the chrome-molybdenum machined more easily than either of the other steels. In the case of the 3.5 per cent nickel, the chrome molybdenum, with a hardness of more than 320 appeared to machine as easily as the nickel steel with about 270 brinell. In four different operations, all that were reported on the increased life of the tools without regrinding was from 135 to 320 per cent when working on chrome-molybdenum.

Another report states that when working on chrome-molybdenum steel, the number of pieces machined without regrinding the tools was 333 per cent more than with chrome-nickel, although the brinell hardness on the molybdenum steel was about 40 points higher.

In a laboratory test the machining qualities of chrome-molybdenum and nickel-chrome steel were obtained by heat treating a specimen of each in exactly the same manner and at the same time. The physical properties of both were similar, with a slightly higher brinell on the

chrome-molybdenum. These specimens were placed in a lathe and while the feed, shape of tool and depth of cut were kept constant, the speed was increased until one or the other turned to a blue color. This occurred first with the chrome-nickel and when it did occur there was no discoloration apparent on the piece of chrome-molybdenum.

The following is verbatim from another report of one of our largest motor manufacturers: "The remarkable forging, heat treating and machining qualities of the chrome-molybdenum steel, however, which have been outlined in the first part of this report will insure increased reliability with an actual saving in manufacturing cost which will more than offset the slight increase in the cost of steel."

"It must be remembered, however, that a unique quality of this steel is the easy machineability and its consequent effect on the wear and tear of tools. A large percentage of overhead cost is accounted for by the expenditure for fixtures and cutting tools, especially the latter. We have shown that the life of cutting tools is at least 200 per cent longer when working on molybdenum steels than with nickel or chrome nickel steel and this has been true even though the brinell hardness of the molybdenum steel was higher. We have demonstrated that for a corresponding elastic limit or brinell hardness, chrome-molybdenum steel machines much more easily than the chrome-nickel and the nickel steels; also that it will machine with equal facility when treated to show a brinell hardness of about 60 points higher. This quality can be made use of in one of two ways: either by producing parts of much greater strength and possessing a higher factor of safety; or by leaving the physical properties approximately the same as with other steels and effecting a great saving in machining cost and increasing largely the production in the machining departments.

From this standpoint alone the saving in tools and increased production due to the machineability of this steel should effect the slight increase in cost of the raw material even though no advantage was derived from the properties already mentioned, such as forging quality, greater facility in heat treatment, fewer rejections and increased factor of safety.

Having covered in an incomplete way the subject of molybdenum steels in general, it might be advisable to run over hastily the specific types of steel and their uses.

Straight molybdenum steel may contain, of course, any desired carbon content with the molybdenum running from 0.20 up to 1.00 per cent but the most used types, known as MOX 1 and MOX 2, containing respectively, 0.20-0.30 and 0.30-0.40 per cent carbon and 0.60-0.70-0.80 per cent molybdenum. These particular steels are not used extensively because the benefits of molybdenum are to a large extent lost if not augmented by some other alloy, such as chrome or nickel.

Tensile results on straight molybdenum steels quenched from 1500 degrees Fahr. in oil and drawn at 1000 degrees Fahr. are:

	Elastic limit, pounds per square inch	Ultimate strength, pounds per square inch	Elongation, per cent	Reduction in area, per cent	Brinell
MOX 1	75,400	96,000	25.4	66.7	228
MOX 2	123,500	139,600	18.5	60.8	351

Chrome-molybdenum steels are divided into four types and three classes. The first class contains 0.25 to 0.40 per cent molybdenum; the

second 0.50 to 0.75 per cent; and the third, 0.75 to 1.00 per cent. Most of the molybdenum steel, however, now being manufactured falls under the first class and it is only in exceptional cases where unusual qualities are desired that the second or third classes are specified. The four types are specified as follows:

	Carbon per cent	Chrome per cent	Manganese per cent	Molybdenum per cent
Mo. 1	0.15-0.23	0.70-1.00	0.40-0.70	0.25-0.40
Mo. 2	0.23-0.30	0.80-1.10	0.50-0.80	0.25-0.40
Mo. 3	0.30-0.40	0.80-1.10	0.50-0.80	0.25-0.40
MS	0.40-0.60	0.80-1.10	0.60-0.90	0.25-0.40

These steels are by all odds the most used in regard to tonnage and are fast being adopted by automobile and tractor manufacturers, agricultural implement makers and the machinery manufacturing trade in general. At least two of the largest automobile manufacturers in this country will probably adopt this steel for use in their cars in the near future and both are planning in adopting it as a universal steel; that is, ordering a certain carbon and using the high heats for oil-quenching stock and the low heats for case-hardening. It is suitable for use in gears, axle shafts, transmission shafts, crankshafts, connecting rods, etc., in automobiles and for corresponding parts in other machinery.

One of the leading automobile frame makers in the country is just concluding some experiments on this type of steel which furnish an interesting comparison with nickel-chrome steel. Both steels were furnished in the same gages and both were heat treated alike. The nickel-chrome analyzed: Carbon, 0.26; manganese, 0.51; nickel, 1.26; and chromium, 0.59 per cent. The chrome-molybdenum steel analyzed: Carbon, 0.22; manganese, 0.43; nickel, 0.0; chromium, 0.59; and molybdenum, 0.35 per cent.

The tensile test on an 8-inch test piece 3-32-inch thick showed:

	Elasticity limit, pounds per square inch	Ultimate strength pounds per square inch	Elongation in 8 inches per cent	Reduction in area per cent
Nickel-chromium....	112,000	130,000	6.2	30.5
Chrome-molybdenum.	135,050	146,900	8.4	37.4

The frames fabricated for a 6-cylinder passenger automobile made up of carbon steel, weighed with the hangers and fittings 225 pounds, while made up of molybdenum steel with the hangers and fittings the weight was reduced to 128 pounds. The question is whether the lighter frame will have the required stiffness, the same point having arisen in the manufacture of a front axle for one of the best known cars when the weight of the axle was reduced approximately 25 per cent by the use of chrome-molybdenum steel, but the stiffness was so affected that there was a constant whip which reduced the life of the tires greatly.

The last type of steel, MS, with the higher carbon and chrome has proved to be successful for use in springs. This is one of the uses where the high drawing temperature has a peculiar advantage as it reduces the liability of breakage without diminishing in any way the resilient properties of the spring.

Nickel-molybdenum steels can contain nickel in all proportions, but the largest tonnages which have been made fall into one of three types. The NM1 type has 0.20 to 0.30 per cent carbon and the NM2 type contains 0.30 to 0.40 per cent carbon while the nickel in both cases is about 3.50 per cent. The third type contains 2.50 per cent nickel with carbon from 0.25 to 0.35 per cent.

The use of nickel-molybdenum steel was developed during the war in the manufacture of light armor for the baby tanks. The French manufactured these tanks using a heavy manganese steel casting for the turret and to protect the gun. It was thought that the excessive weight of this armor could be reduced by using rolled and pressed shapes, but the penetrative effect of the German bullet was so great that it was a difficult problem to insure adequate protection to the crew. Finally results were obtained with armor ranging from 1-4 to 5-8-inch in thickness that seemed to assure the success of the undertaking but the steel used, a nickel-chrome gave extremely erratic results under the ballistic test and machined with such difficulty that frequently the manufacturers of safes and vaults with their special tools could not touch it. At this juncture, molybdenum was substituted for the chrome in the analysis with almost incredible results. With the straight high-nickel and the nickel-chrome 76 per cent of the plates were accepted after passing the ballistic test, which included firing at the plates at a range of 50 yards with the United States armor piercing bullet having a muzzle velocity of 2800 feet per second. The addition of 0.50-0.60 per cent molybdenum to the nickel steel resulted in 99.5 per cent acceptance of plates, not to speak of the great saving made by the comparative ease of machining. Before turning to molybdenum a large percentage of the plates would crack in the straightening process. This loss differed more or less with the different analyses used, but in no case did it run below 10 per cent and it occurred even after a 400 degree Fahr. draw in oil. When a nickel-molybdenum plate was used, this crackage was eliminated and it was soon found that the dispensing with the draw did not increase the crackage to any appreciable extent or influence the ballistic test. It is unfortunate that none of these tanks reached the front sectors before the armistice, so that the results of actual service could be determined.

However, this case was not the only one of molybdenum used in actual war material for it is well known that the Germans made extended use of this alloy, particularly in their large gun tubes, where it showed a very great resistance to erosion, the bane of the artilleryman.

As for the present day commercial uses of the nickel-molybdenum steel it can replace satisfactorily the nickel steels or the nickel-chrome steels where toughness under load is required and where ease of machining is a vital factor.

During the war in the development of the Liberty motors, a nickel-chrome-molybdenum steel was used extensively for crankshafts and showed superior results. This type of steel is now known as LM and analyzes: Carbon, 0.25-0.35; chrome, 0.70-1.00; nickel, 2.75-3.25 and molybdenum from 0.30-0.50 per cent.

The last type is the chrome-vanadium-molybdenum steel which was made for use as a steel par excellence. It has all the advantages of the chrome-molybdenum with the added qualities conferred by vanadium, which are well known.

Having now covered the types and uses of molybdenum steels, it might be appropriate to add a word of explanation regarding the cost of this steel.   A great many users are prone to remarks "What! Use a steel the alloy in which cost $2.50 a pound!"   It is, of course an erroneous assumption to judge the cost of a steel by its alloys.   It should be judged from a basis of performance, production and rejections, and viewed from this angle, a steel which costs a cent or two more a pound may be far cheaper actually than the steel whose first cost is lower. Molybdenum is not the cure-all of the steel industry.   It will not make bad steel good.   It can be misused and is misused today.   There are places for it and there are places where it is distinctly undesirable, and, like everything new, it seems to have been either overenthusiastically received or else uselessly condemned.   Only recently a gentleman stated that he thought molybdenum steel might be the very steel he was looking for.   When asked what qualities he desired he modestly replied that he would be satisfied with an elastic limit of 350,000 pounds per square inch with an elongation of 20 per cent.   And today we received a complaint from a customer who was comparing chrome-molybdenum with nickel-chrome and chrome-vanadium steel.   His tensile results showed the elastic limit on the molybdenum to be about 40,000 pounds lower per square inch than on either of the other steels. Investigation showed that, while both the other steels had been heat treated, the chrome-molybdenum was being tested just as it was rolled.

If the buyer of steels would balance one fact with another, selecting his material on the broad basis of general fitness, doubtless there would be many more uses developed for this type of steel.   But even as it is, taking instances only from the experience of one company, molybdenum has been used for such widely varying purposes as automobile parts, aeroplane motor and fuselage parts, section steel for reapers and other agricultural machines, armor plate, battering tools, such as machinist's hammers, edge tools, such as hatchets and chisels, gears, large and small, springs of all kinds, shafting for heavy and light machinery, balls for ball bearings, shovels, rifle barrels, rivet sets, and many other uses. It was in the first planes to cross the Atlantic and was used to some extent in the largest land plane ever built in this country.   And it will not be long until the preliminary announcement is made of an all-molybdenum automobile in which, it is said, every stressed part will be of molybdenum steel.

*

SERIES OF ARTICLES IS POSTPONED

As a result of delay in securing illustrations, the series of 10 articles on the carbonizing process by Theodore G. Selleck, Chicago, and announced to begin with this issue, has been postponed until a later issue of TRANSACTIONS. "First Principles of the Carbonizing Process—A Consideration of the Fundamental Facts and Factors of the Process" is the title of the first article which will appear as soon as the illustrations are secured.   Other articles in the series will appear from time to time.

A RESEARCH IN CASE CARBONIZING
By G. S. McFarland*
(A Paper Presented at Philadelphia Convention)

This paper compares 5 per cent nickel steel, a carbon steel and a chrome vanadium steel when used for case carbonizing. The steels used for the tests had analyses as follow: The carbon steel contained 0.22 C., 0.50 Mn., 0.01 P., and 0.03 per cent S. The chrome vanadium steel contained 0.19 C., 0.57 Mn., 0.008 P., 0.025 S., 0.74 Cr., and 0.16 per cent Va. The nickel steel contained 0.18 C., 0.51 Mn., 0.01 P., 0.02 S., and 0.49 per cent Ni.

The procedure was as follows: A bar of each analysis of steel was turned down to 5-8-inch diameter and nickel at suitable intervals to facilitate breaking after being hardened. For the packing the compound known as Ajax case hardening compound was used. The pieces were packed in this in a suitable box and sealed. This was placed in a furnace and slowly raised to a temperature of 1650 degrees Fahr., kept there for a period of 3 hours, and allowed to cool in the furnace over night, being opened the following morning.

The specimens were studied, physically and microscopically in three conditions: (1) As they were when taken from the case carbonizing operation; (2) after being heated to 1425 degrees Fahr, and quenched; and (3) after being heated to 1800 degrees Fahr., and quenched then reheated to 1425 degrees Fahr. and quenched. In each case the specimens were polished and etched for microscopic examination and for photographing. The accompanying illustrations are in eight series numbered to VIII, Figs. 1-24, and each series contains three microphotographs, one each of carbon, chrome vanadium and nickel steel. All the photographs in any one series are from specimens that have had identical heat treatment. The photographs of Series I, Fig. 1-3, are magnifications of 60 diameters; those of Series II, Fig. 4-6, 100 diameters; while all the remainder are 600 diameters.

Let us first consider the specimens in Condition 1, that is, as they come from the furnace. The photographs of Series I, Fig. 3, are of the samples etched with a dilute solution of nitric acid in alcohol. These were taken to show the depth to which the carbon has penetrated. It will be seen that there is little difference in the three steels. Series II, Figs. 4-6, shows the specimens after being etched with a solution of sodium picrate which colors the carbide or iron, cementite, black. In the carbon steel, Fig. 4, it will be seen that the excessive cementite is in the form of a coarse network, while in the chrome vanadium steel, Fig. 5, the network is fine. In the nickel steel, Fig. 6, we find something different, the nickel unites with the cementite to form a complex double carbide of iron, about which little is known. Series III, Figs. 7-9, is the same as Series II, but magnified 600 times. Here the differences noted before have become more marked.

Series IV, Figs. 10-12, shows photographs of the cores of the samples as they come from the furnace. The sames were etched with dilute solution of nitric acid in alcohol. In the case of the carbon steel Fig. 10, we find large crystals of well developed pearlite in the laminated condition occurring as islands in a matrix of ferrite, in other words, nearly pure iron. In the case of the chrome vanadium steel, Fig. 11, we still find the islands of pearlite in a matrix of ferrite, but here the pearlite is not so

---

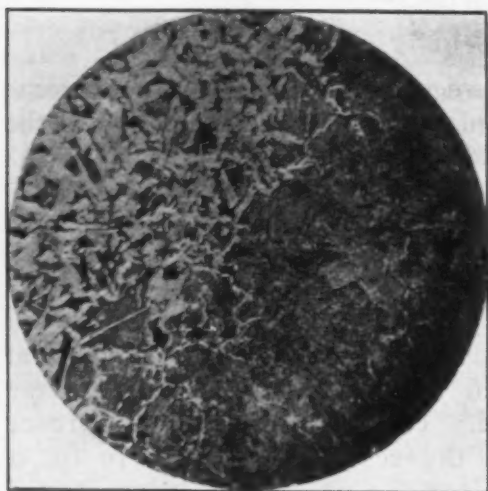*Metallurgist, Jeffrey Mfg. Co., Columbus, O.

SERIES I

SERIES II
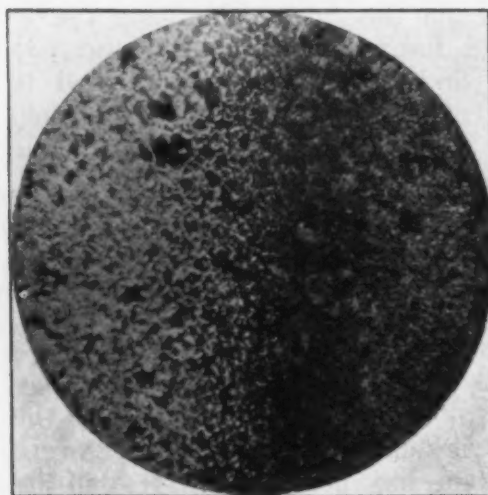

Fig. 1—Carbon Steel x 60

Fig. 4—Carbon Steel x 100

Fig. 2—Chrome Vanadium Steel x 60

Fig. 5—Chrome Vanadium Steel x 100
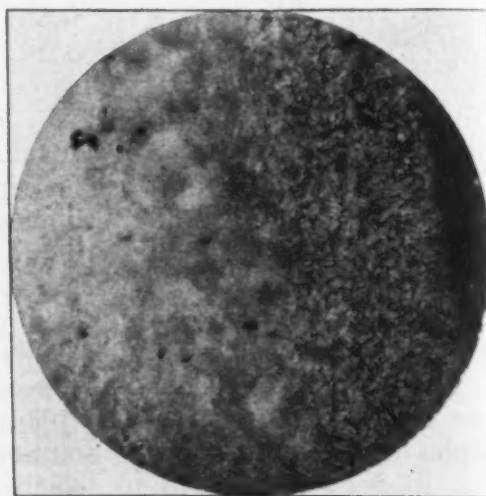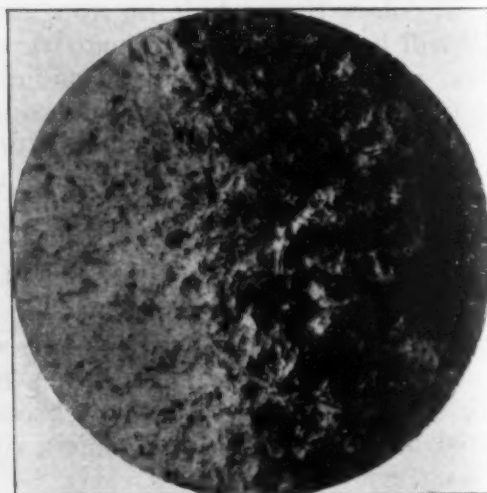

Fig. 3—Nickel Steel x 60

Fig. 6—Nickel Steel x 100

well developed; also the pearlite particles are smaller and greater in number. This will be pointed out as an advantage a little later. In the nickel steel, Fig. 12, we find that the structure is much finer than in the preceding two steels and is all broken up. It seems to be a mixture of lamellar pearlite, granular pearlite and ferrite.

The following results show brinell and shore hardness of the steels in Condition 1, as they were taken from the furnace.

Specimen	Brinell	Shore
Carbon	99	18
Chrome Vanadium	121	21
Nickel	174	23

Let us now consider the steels in Condition 2, that is, hardened at 1425 degrees Fahr. Samples of each of the steels were clamped together in a frame to insure identical treatment, put into a small gas furnace and slowly raised to 1425 degrees Fahr., soaked at that temperature a few minutes, and quenched in an abundance of cold water.

We will first consider the condition of the metal in the cores, taking them in the usual order. Series V, Figs. 13-15. In the carbon steel, Fig. 13, we see that each island of pearlite has been converted into martensite surrounded by a border of a darker material, which is troostite. The cooling was not sudden enough to remain all the martensite in the original form, thus part of it decomposed into troostite and was retained as such. We see the ferrite matrix the same as in the specimen that had not been treated. The reason the matrix of ferrite and the pearlite of the original steel did not dissolve in one another, and when quenched give a uniform structure throughout, is that the highest critical point of this steel lies in the neighborhood of 1700 degrees Fahr. and until that temperature was reached a complete solution could not take place. In the chrome vanadium steel, Fig. 14, we see somewhat the same result as in the carbon steel. The islands of pearlite have been converted into martensite surrounded by a matrix of ferrite, but here we have no troostite precipitated. In the original steel, the particles of pearlite being smaller and of greater number than in the carbon steel, we should expect to find a closer and stronger looking steel after being quenched than was the case with the carbon steel, and indeed such is the case.

It is with the case of the nickel steel, Fig. 15, however, that we see the most striking result. Here the particles of pearlite and the ferrite matrix have completely dissolved in one another, and upon quenching a fine grained structure consisting wholly of martensite, has been retained.

To one not familiar with metallography, the results of Condition 2 tabulated below will present the physical properties in a striking manner.

Specimen	Brinell	Shore
Carbon	235	29-30
Chrome Vanadium	262	36
Nickel	402	50-52

Let us now consider one of the cases after having received the above treatment, namely, quenching from 1425 degrees Fahr. and illustrated by Series VI, Figs. 16-18. In the carbon steel, Fig. 16, we have a good martensite structure, but shot through with a coarse network and needles of excessive cementite which, of course, form places of weakness. In the chrome vanadium steel, Fig. 17, we have a still finer martensitic structure than the preceding. Here the excess cementite is in the form of a fine network com-

pletely breaking up the mass.   In the nickel steel, Fig. 18, we have a fine mar-
tensitic structure throughout with no excess cementite, probably due to the
fact that the complex double carbide of carbon nickel and iron referred to
above is completely retained in solution.   It will be seen from the illustration
that the structure is homogeneous throughout with no planes of weakness
such as are contained in the other two steels.

As the brinell test is not satisfactory on case hardened articles, only the
shore hardness for this case is given.

Specimen	Shore
Carbon	80-84
Chrome Vanadium	85-89
Nickel	70

In the above we see that the nickel core has dropped behind the other
two.   By experiment this was shown to be due to too high a hardening
temperature.   A temperature of 1325 degrees Fahr. and quenched gave re-
sults comparable to the other two, shore 85-87.

We now come to Condition 3, in which the specimens were first heated
to 1825 degrees Fahr. and quenched in cold water; then reheated to 1425 de-
grees Fahr. and quenched in cold water.

Let us first consider the condition of the metal in the cores, as shown
by Series VII, Figs. 19-21.   In the carbon steel, Fig. 19, we find that a par-
tial solution of the martensite, troostite and ferrite has taken place, but the
structure is far from perfect and leaves much to be desired.   However, it is
perhaps as good a structure as is usually obtained in regular working con-
ditions with a like grade of low carbon steel.   We find that the chrome
vanadium steel, Fig. 20, is a great improvement over the carbon steel, there
being but few particles not in solution, the structure for the most part being
finely martensitic.   In the nickel steel, Fig. 21, everything is in solution as
before and the structure is martensitic, but of a coarser texture than that of
the steel having received but the single treatment.

The shore tests of this case are as follows:

Specimen	Shore
Carbon	32
Chrome Vanadium	38
Nickel	48

While a comparison to those steels in Condition 2 show that there is a
slight increase in hardness for the carbon and chrome vanadium steels, while
there is a corresponding decrease in that of the nickel steel.   The brinell
tests for these samples are not given owing to the fact that the samples are
too small to make the tests of value.

In comparing the cases of these steels as last treated, Series VIII, Figs.
22-24, we find that the excessive cementite in the carbon and chrome vana-
dium steels, Figs. 22 and 23 respectively, the structure has been coarsened
somewhat. The shore tests are as follows:

Specimen	Shore
Carbon	80-83
Chrome Vanadium	80-83
Nickel	80

The double treatment as applied to these steels increases the useful
properties of the carbon and chrome vanadium steels by toughening their
cores, and decreases from those of the nickel steel by weakening its core.
The hardness of the cases are about the same in all cases.

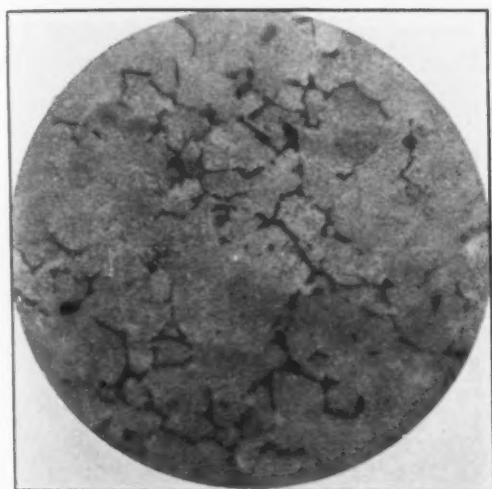SERIES III   SERIES IV

Fig. 7—Carbon Steel x 600   Fig. 10—Carbon Steel x 600

Fig. 8—Chrome Vanadium Steel x 600   Fig. 11—Chrome Vanadium Steel x 600
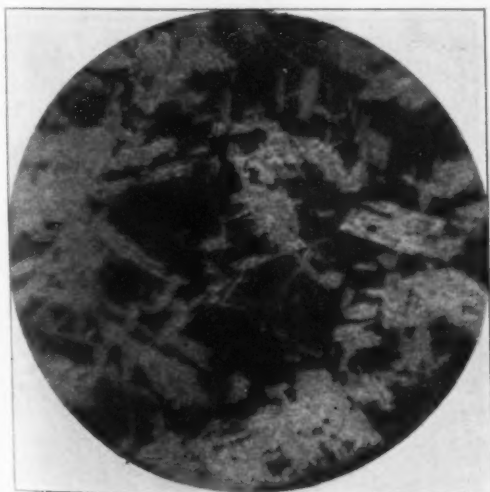
Fig. 9—Nickel Steel x 600   Fig. 12—Nickel Steel x 600
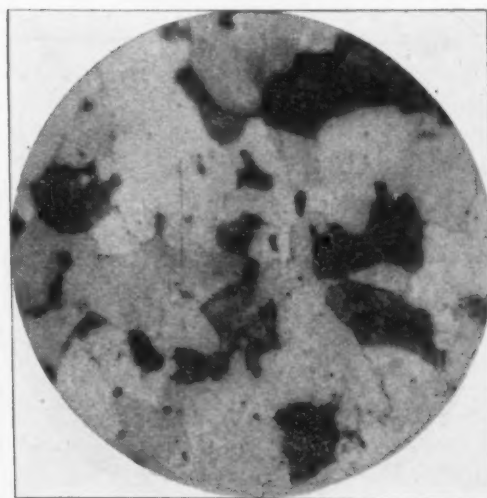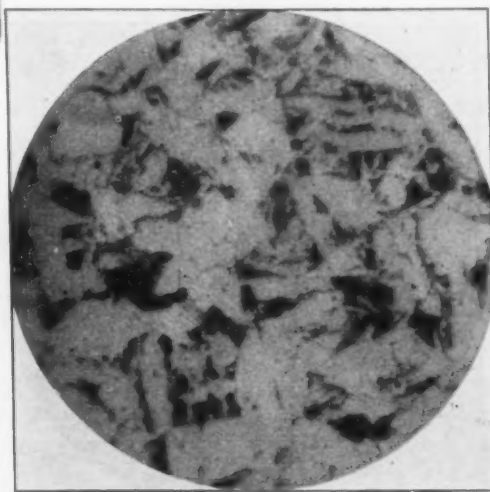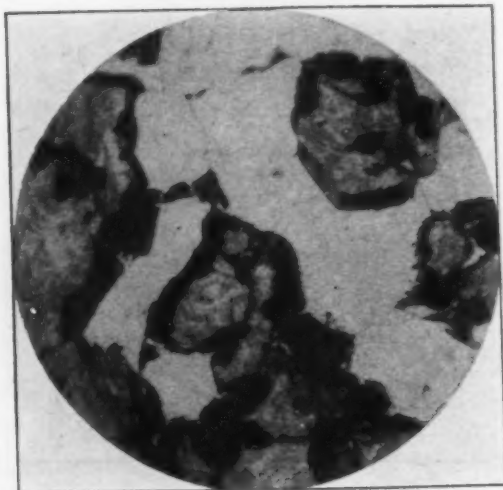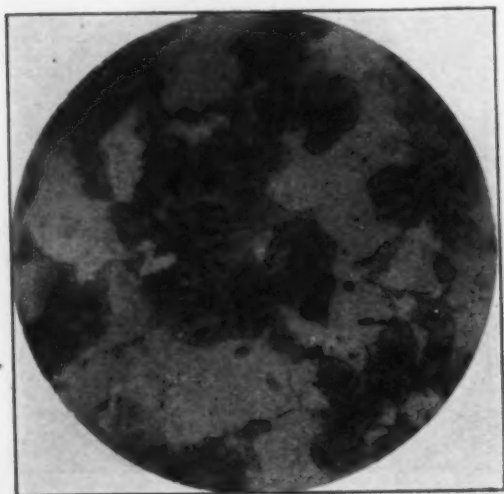
SERIES V

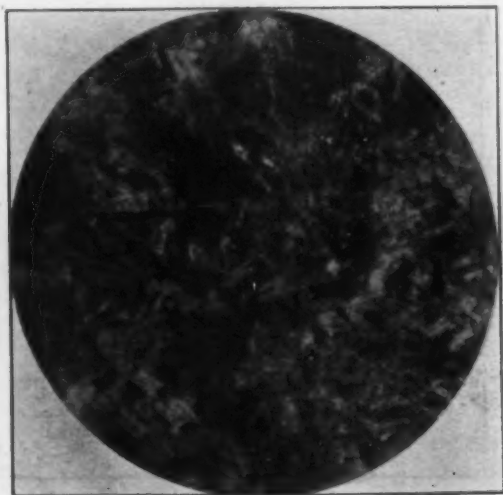Fig. 13—Carbon Steel x 600

Fig. 14—Chrome Vanadium Steel x 600

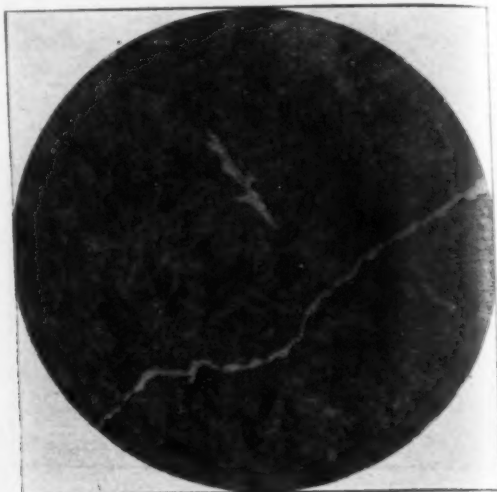Fig. 15—Nickel Steel x 600

SERIES VI

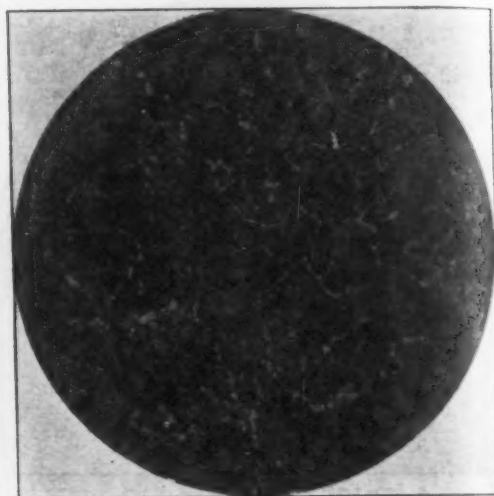

Fig. 16—Carbon Steel x 600

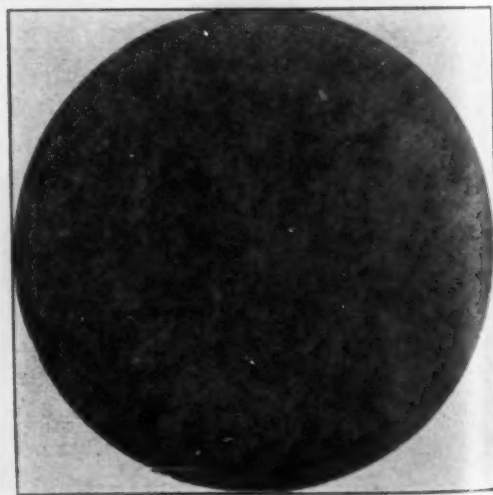

Fig. 17—Chrome Vanadium Steel x 600

Fig. 18—Nickel Steel x 600

I think it will be seen that for ease of working, that is a single heat treatment, and for its higher physical properties, the nickel steel is superior to the other two.

The steels in this research have been treated alike throughout at purely arbitrary temperatures, and there is no doubt that the physical properties obtained could be improved upon by a research on any particular steel, finding out its separate needs and peculiarities as regards the packing material, the length of time of the carbonizing, and the temperature or temperatures to which it is heated before quenching.

DISCUSSION OF MR. McFARLAND'S PAPER

MR. HOLBING: I would like to know whether those physical properties obtained are not rather high. They are rather unusual, particularly to obtain 70,000 pounds per square inch elastic limit from case hardening of a straight carbon steel.

MR. McFARLAND: Those steels after experimenting are found to be practically the ideal condition. They are a little better than the commercial.

MR. HOLBING: It is not possible in some of the carburized cases.

MR. McFARLAND: I have ground those off sufficiently. I think this 5 per cent nickel steel is a remarkable steel. Along with my physical tests on those I have carried on a cold bend test. I have taken all these steels, first quenched at 1100, 1200, 1300, 1500, and on up to 1800 degrees, Fahr. pulled them and obtained a decided difference in the physical properties by watching this cold bend test. The specimen I have standardized upon for this test is about 6 inches long and 3/4-inch in diameter and after treating, carbonizing, and putting through the regular process, I grind the case off and then with a bending device which I have devised have applied it under an Olsen or a Reilly test, so all specimens get the bend test.

MR. HOLBING: Could I ask what was the carbon content of that steel?

MR. McFARLAND: 0.22 per cent. I got these fairly close together; carbon 0.22 per cent, chrome vanadium 0.19 per cent, and the nickel steel 0.18 per cent, so there is only 3 or 4 pounds difference in them.

MR. HOLBING: It occurred to me that the chrome vanadium and the nickel steels were rather high too; 70,000 pounds per square inch was beyond the bounds of heat treated 0.20 carbon steel.

MR. McFARLAND: I will agree with you that commercially we would not get quite as high test as that.

MR. HOLBING: We have had some elegant steels, but we have never been able to get anything like that.

MEMBER: Do I understand the gentleman to say he can not get 70,000 pounds per square inch on that steel?

MR. HOLBING: Yes.

MEMBER: I have obtained 90,000 pounds per square inch.

DR. HARTZELL: Mr. Lane of the York Mfg. Co. requested me to ask a question for him. He asked me the same question and I could not answer it. The point is not directly bearing on your paper, but indirectly so, but is this: Is it possible to select a steel commercially with some additional alloy or alloys which may be cased, air quenched, and be hard?
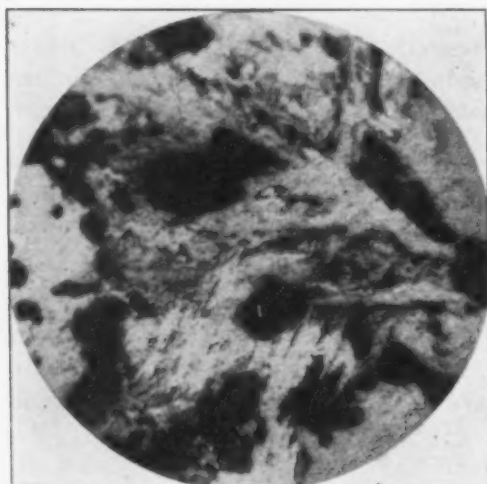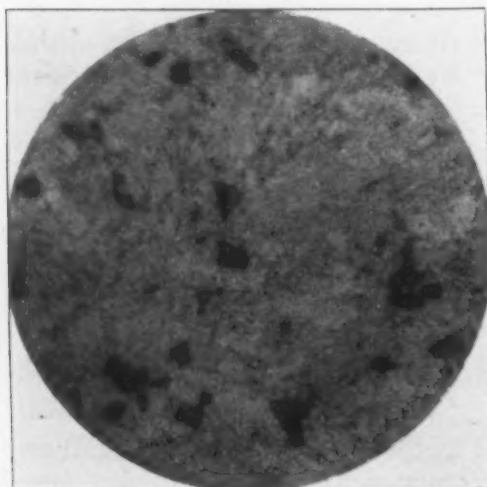
SERIES VII

Fig. 19—Carbon Steel x 600
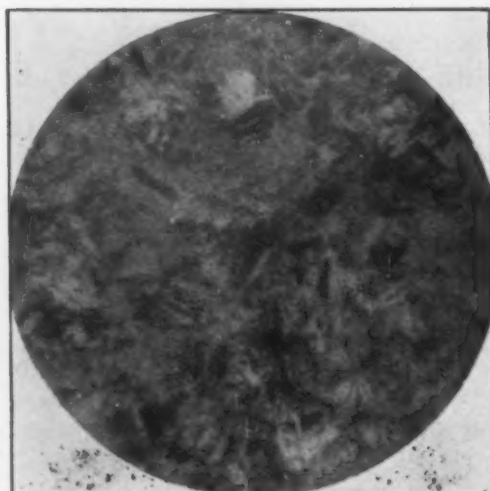

Fig. 20—Chrome Vanadium Steel x 600

Fig. 21—Nickel Steel x 600
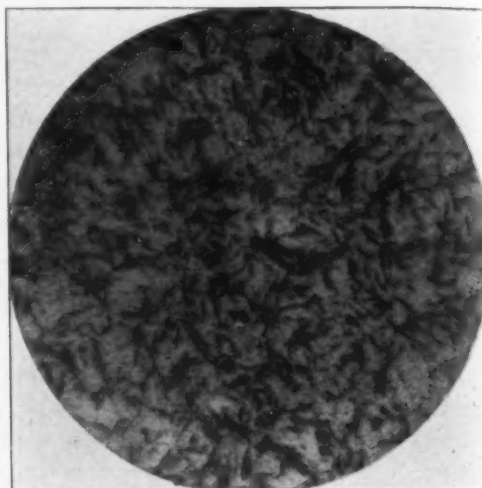
SERIES VIII

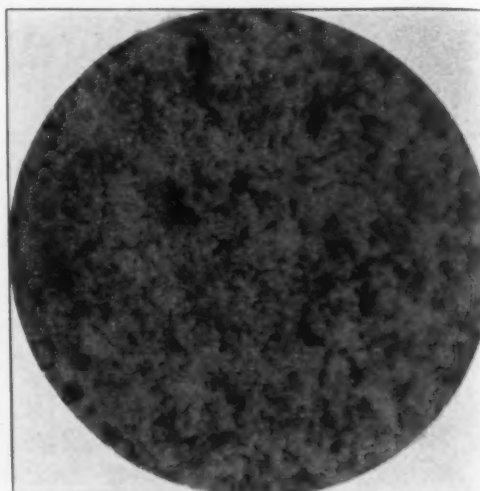

Fig. 22—Carbon Steel x 600

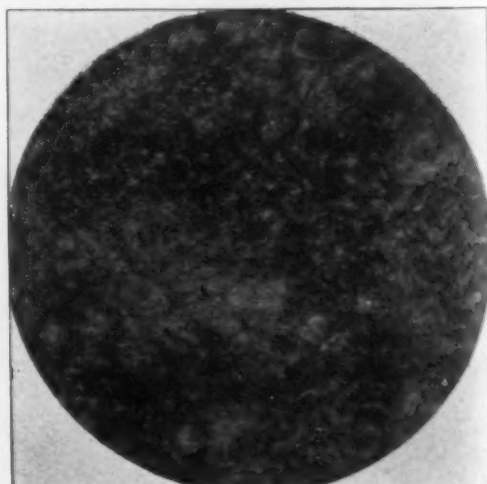

Fig. 23—Chrome Vanadium Steel x 600

Fig. 24—Nickel Steel x 600

MR. McFARLAND: Yes.

DR. HARTZELL: Mr. Lane would like to have you explain.

MR. McFARLAND: I have been experimenting with nickel steels as high as 9 and 10 per cent, and from tests that I have made we have obtained about a 9 per cent nickel steel with a 0.15 to 0.20 per cent carbon content which air hardens. When you put a scleroscope on that, it will show only a hardness of about 30 or 35 feet that is hardly a machine tool and as far as the work that I have done upon it is concerned, it is almost impossible to commercially anneal that so it can be machined.

MR. HARPER: I would like to inquire of the speaker if the nickel steel which, after quenching, gave a lower brinell hardness than the straight carbon steel would show an increase in hardness after a draw at a relatively low temperature?

MR. McFARLAND: I have not determined that.

MR. HARPER: I wondered if it would also show an increase in hardness after drawing.

MR. McFARLAND: You mean quenching at a temperature of 1325 to 1350 degrees Fahr.? It will on the case, but the structure of the core is really below the recalescent point of the steel itself, and you would not get the physical properties of the core.

MR. HARPER: It occurred to me there might be an increase in hardness there.

MR. McFARLAND: I have some interesting figures on the physical properties of these 5 per cent nickel steels quenched at different temperatures in conjunction with the cold bend test that might be interesting to some. I will be glad to show those to anybody who would like to see them. I believe a great deal can be obtained by means of this cold bend test. In connection with the working along of the physical properties much can be determined. You get a point in there where you can get an exceedingly high elastic limit and great ductility, as shown by the bend test.

MR. STRENGER: I would like to ask if you can give us an explanation of just why copper plating prevents carburization?

MR. McFARLAND: I cannot.

CHAIRMAN: Maybe somebody here would like to ask the question why it does not at times. (Laughter).

A NOTE ON DOUBLE PREHEATING HIGH SPEED TOOLS FOR HARDENING

By A. E. MacFarland*

(A Paper Presented at Philadelphia Convention)

A few years ago my friend and associate, Arthur G. Henry, called my attention to double preheating high speed tools before subjecting them to the high temperature of the hardening furnace. Since that time a rather comprehensive study has been made of various methods of hardening high speed steel, which has brought out strong points in favor of double preheating.

The practice of hardening high speed steel tools using a double preheating treatment has been outlined in several unpublished addresses and papers by the author somewhat as follows:

Three furnaces are used for the hardening operation, being maintained at respective temperatures of 950-1000 degrees Fahr.; 1500-1600 degrees Fahr. and 2300-2375 degrees Fahr. After the tools are finished, machined and annealed to relieve all strain, they are placed in furnace No. 1 on suitable jigs to raise them from the hearth of the furnace and to enable them to heat more uniformly. This furnace may be loaded to capacity and is used as a stock furnace to supply furnace No. 2.

Furnace No. 2 is the second preheating furnace operating at approximately 1525 degrees Fahr. The tools on their jigs are transferred from furnace No. 1 to furnace No. 2, allowing them to remain subjected to a temperature of 1525 degrees for a period of time sufficient to thoroughly and evenly saturate the tool being hardened. Care should be taken not to leave tools for too long a period of time in the second furnace and for this reason it is not advisable to have more than three good sized tools in this furnace at one time.

Furnace No. 3 is the regular high temperature hardening furnace and is supplied with tools from the second furnace. The tools are allowed to remain in the high temperature furnace operating at about 2325 degrees Fahr. for a predetermined suitable length of time, which has been found to impart the most desirable properties to the tool. Tools are quenched from this furnace usually in oil and subsequently drawn to 1050 degrees Fahr. in either lead pot, saltpeter pot, or electric furnace.

The practice briefly outlined above constitutes what large manufacturers of small tools have found to give best results in hardening high speed tools. Before going into the reasons and advantages to be derived from the double preheating operation, a short discussion of decarbonization is probably advisable.

Decarbonization is the reverse of carbonization. When a piece of steel is carbonized it is packed in a suitable mixture, which, upon being heated, transfers carbon from the mixture to the surface of the steel. Decarbonization, on the other hand, consists in extracting the carbon from the surface of the steel being treated, and is manifested by a soft surface layer of metal which will not harden due to the absence of carbon. Decarbonized surfaces can usually be detected by a file after hardening.

---

*Metallurgical engineer, Vanadium Alloys Steel Co., Latrobe, Pa.

by inspection of the fractured surface, or by microscope examination. None of these tests are infallible although usually adequate for inspection purposes. The best test for decarbonization consists in analyzing the chips removed from consecutive layers of the steel 0.005 of an inch thick. These chips from the separate layers can easily be analyzed for carbon and any differenes noted in the surface carbon content to that of the body of the steel.

Decarbonization causes considerable trouble to the tool hardener and in order to prevent the same it is necessary to inquire into the basic cause of the phenomena. Decarbonized surfaces are caused by scale, therefore, it is advisable that all tools exhibit surfaces entirely free from scale before hardening. This is not so necessary in the case of tool bits, or roughing tools, which are ground to shape after being hardened as decarbonized surfaces are easily removed by the emery wheel. In the case of circular forming cutters, hobbs and intricate milling cutters, it is very necessary as the grinding allowances on these tools are usually small and a decarbonized surface absolutely ruins the tool for cutting purposes. If the formation of scale can be eliminated or reduced to a minimum the danger of decarbonization of surface is lessened.

Reducing atmospheres in furnaces tend to reduce the tendency toward scaling, but when steel is once scaled, a reducing atmosphere is more apt to produce decarbonization of surface than an oxidizing atmosphere. On the face of it, this statement seems almost contradictory, but its truth will be realized when one considers the chemistry involved. Scale as scale will not extract carbon from the surface of the steel in an oxidizing atmosphere, however, when a reducing atmosphere is maintained the scale is reduced from iron oxide to metallic iron and the atmosphere of the furnace works in connection with the steel just under the scale, which gives up part of its carbon to reduce the scale to the iron. In this way a decarbonized surface is formed and is proportional to the nature of the scale, the quantity of the scale, and the temperature of the furnace. Steel does not scale rapidly until it has attained a temperature of about 1200 degrees Fahr. Therefore, it can be heated safely for relatively long periods of time at a temperature between 950 and 1100 degrees Fahr. without damage due to scaling.

This is one of the very important advantages double preheating has upon a single preheating operation prior to hardening. Placing a cold tool in the preheating furnace at a temperature of 1525 degrees Fahr. subjects the tool to a scaling temperature under ordinary furnace conditions and the outside of the tool will exhibit a relatively heavy scale before it is up to the required temperature. On the other hand, if a tool is preheated to 1050 degrees Fahr. before being placed in the 1525 degrees Fahr. furnace, it will require a correspondingly shorter time to come to a temperature with a corresponding decrease in the amount of the scale form.

Double preheating also increases the production of the tool hardening plan inasmuch as it cuts down the time necessary for preheating.

It is well recognized that heavy masses of high speed steel in the form of tools require exceptional care in heating. If heated too rapidly these tools will develop strains which cause them to crack. Double preheating, therefore, decreases the tendecy for large tools to crack in the

hardening process as it provides a method of more gradually heating them before subjecting them to the high temperature of hardening.

In outlining this method it is not desired to convey the impression that good results cannot be obtained by the single preheating treatment in common usage as there is too much of the personal element involved in the hardening of high speed steel to set down hard and fixed rules to apply to every plant and each individual. Neither is it desired to convey the impression that high speed steel is especially complicated in its treatment. It should be emphasized, however, that the more care and attention given to the gradual heating of high speed steel tools before hardening, the better will be the performance of the tools in actual use.

The author is personally acquainted with several cases in large size tool rooms producing tools in quantity where double preheating has spelled the difference between failure and success.

DISCUSSION OF MR. MacFARLAND'S PAPER

MR. REARDEN: Why do we get an apparent increase in decarbonization from the furnaces equipped with the one pipe system than we do from furnaces equipped with the two?

MR. MACFARLAND: You mean burners? Well, the question of furnace design, of course, enters into the decarbonization quite extensively as the atmosphere of the furnace is more or less determined by its design. I am not exactly familiar with what you mean by the two-burner or the one-burner type of furnace. I am satisfied in my own mind that a furnace can be designed for a satisfactory hardening of high speed steel with just one burner, but it is a question of whether the tools are subjected to a blast of hot furnace gases or whether they are protected rather well from hot furnace gases. I think that more important in considering decarbonization.

MR. REARDEN: My own experience is, that taking the one pipe with practically no control, you cannot get what I call a drier heat. That is my notion. You are getting more decarbonization than you would with the drier flame, as I put it myself.

MR. STAGG: I regret very much that Prof. Henry Howe is not here. In Professor Howe's absence, and having been one of his students some time ago, I want to say something which I know Professor Howe would say were he here. I am quite sure that Professor Howe when he thinks of the effect of the removal of carbon from the outside would characterize that effect as decarburization rather than decarbonization. Or, the reverse, as carburization and not carbonization. That word I hear misused wherever I go, and I am trying to bring it out so we will all talk in the same terms and talk correctly. There is also one question I would like to ask Mr. MacFarland. He mentioned conditions for the production and the prevention of decarburization. I wonder if he has done any work along gas analyses which will give us some information as to the actual analyses of gases, either from an oil, gas or coal furnace which will be ideal for the prevention, and which will be ideal for the formation, of decarburized surfaces.

MR. MACFARLAND: I have done nothing along those lines. I have not gone into the thing quite so extensively as that, Mr. Stagg. Have you done any work along those lines?

MR. STAGG: Not enough so that I would want to say anything about it here. (Laughter).

MR. SMITH: With reference to Mr. Rearden's statement about the one pipe system as against the two pipe system, you can get equal results, well, rather,I won't say you can equal results, but you will find, I believe, that you can get better results, with the one pipe system than you can with the two, because you will eliminate the mixtures of air and gas. Take the mixture of air and gas out of the operator's hands, and once you set your mixtures correctly, getting you flue gas correct by the analysis of the flue gas, seeing that you get no free oxygen and no free carbon monoxide, your flue gas will always remains the same. From experiments of the Surface Combustion Co., I believe absolutely no free oxygen and no carbon monoxide gas in your furnace atmosphere is the ideal condition.

MR. MACFARLAND: I feel sure, Mr. Johnson, that you have something to say about decarbonization.

MR. JOHNSON: Mr. Chairman, as Mr. McFarland says, the steel heating furnace having a truly reducing atmosphere would cause decarbonization and scale on the steel when you put it in. The scale instead of coming away clings more tightly and absorbs carbon from the surface of the metal, whereas if the temperature is oxidizing to a certain extent the scale instead of clinging to the steel falls away, because of the formations underneath. As to the atmosphere of the furnace, one has to consider that carbon dioxide there will cause decorbonizations. I made some experiments some years ago along these lines and one has to be careful how they shut the air away for if he shuts the air away he stands a good chance of having some soft spots and decarbonization.

Of course, everybody knows it is not a good thing for a sharp oxidizing flame to impinge directly on the surface of the metal. But we have to guard against conditions approaching reducing conditions just as much. That is one reason a hardening furnace using carbon resistor face is rather a risky furnace to use in those high temperatures. Then I have often wondered about the matter of sweating tubes, whether that is not often a source of trouble—when it is necessary to go so far as to cause sweating on the tubes. I think that has its bearing. Give it a little more time on such extreme heats.

HARDENING HAMMER DIE BLOCKS
By R. B. Kerr*

(A Paper Presented by Title at Philadelphia Convention)

Since the introduction of the modern drop forging hammer, the problem of producing and successfully heat treating large dies to get the maximum of service with a minimum of loss, has engaged the attention of steelmakers and steel treaters alike.

Early in the game it was found that the percentage of loss from hardening from various causes was heavy. Flaws or pipes in the interior of the blocks resulting from improper casting or forging; steel of too high or irregular carbon content; and more especially inadequate tempering room equipment, are among the chief causes of failure. The unfortunate hardener too often is made the goat for the sins, mostly of omission, of both the steelmaker and the shop foreman.

*Foreman, heat treating department, John Deere Harvester Works, East Moline, Ill.

To get around possible loss in heat treating, various kinds of alloy and socalled heat-resisting steels have been tried, with more or less success. Now it is generally conceded, however, that a good sound steel of medium carbon content, when properly hardened, gives the best all round service. The methods suggested herewith for accomplishing this have been in successful use by the writer for a number of years and are offered not with any idea that they are perfection or the only way, but with the hope that they may be helpful.

While die blocks can be heated successfully in either coke or oil furnaces or even in the smith's forge, a gas heated furnace of the oven type is by far the most convenient and satisfactory for this work.

Coke makes a nice clear fire of fairly simple regulation, and with a skillful heater in charge, good results can be obtained. An objection to its use is the frequent presence of impurities, particularly sulphur.

When heating dies the considerable air pressure required to burn fuel oil, makes necessary the most extreme care to prevent scaling or surface decarburization in the parts to be treated. The furnace, therefore, should be of the muffle type, the heating chamber completely inclosed, or if this is not available, the die should for protection be packed face down in a gas tight box of suitable size half filled with charcoal, and the whole thing heated up. If the piece to be heated is of considerable size, the packing box should be made with hinged ends which fold down out of the way so that the die can be lifted out readily by grab hooks or a sling. This "safety first" method entails some extra work and inconvenience, but the results justify it. Personally, the writer can testify through considerable experience that it is better to go to some extra trouble to assure success, than to have an opportunity later on to frame up excuses that will pass when asked to explain "how it happened."

It might be said in passing that this method of pack hardening is excellent for heating dies and tools of nearly all descriptions. The parts come out of the packing box uniformly heated with a surface perfectly free from scale and in the best possible condition for hardening. The process is an old and successful way of heating steel. It deserves to be more widely known and practiced.

Whatever the type of furnace used or the means employed the all important thing is to get a good heat on the die; a thorough slow soaking, uniform heat, for upon that depends to a great extent the success or failure of the operation. Particularly for the benefit of the younger steel treaters it may be said that thorough careful heating, more especially when handling comparatively large blocks of steel, is most essential. It is the author's opinion, based on a long and varied experience in hardening steel, that more dies and tools are ruined by careless heating than from all other causes combined.

For heating, a gas-fired, oven furnace of ample capacity should be used as being most convenient and suitable for the job. If the oven is already hot so much the better, if not, bring it up pretty well before putting in the work. Dies of any description should not be put into a cold furnace. Nothing is gained in time, and besides some chances of surface decarburization are offered with a rapid rising heat.

Place the die in the furnace face down, unless the nature of the impressions makes this impossible; in which event it is good practice to protect the surface from possible gases by laying a closely fitting piece of

asbestos or sheet steel on top while heating. As another precaution, if the die is of considerable size and the impressions are deep or irregular, it is well to bring it up to a dull red heat, about 1300 degrees Fahr. and let it partly cool off in the furnace before taking the hardening heat.

Heat slowly and regularly. The time required of course will vary in proportion to the heating area of the furnace and the size and shape of the piece to be treated. Usually three to five hours are required for drop forging dies of average size. The most important point is, as already mentioned, to get uniform heat throughout the piece. One of the most valuable assets a steel treater can have is the ability to judge or sense correctly when a large block of steel is heated properly throughout. While a pyrometer or other reliable heat measuring device is a valuable aid and guide, it is not everything, neither can it indicate what is going on inside the mass, and the writer has learned from experience that outward appearances in steel die blocks, as in many other materials, are often times deceptive. The average grade of hammer die steel will harden nicely at around 1450 degrees Fahr. and the heat always should be held stationary for at least 15 minutes before removing the die from the fire.

The quenching tank should be of ample size and the water supply arranged so that it can be forced upward against the face of the die with considerable force and volume, using an overflow pipe of sufficient size to take it away. In most cases clean fresh water is all that is necessary, but if extreme hardness is required or if the water is soft or muddy, river water as an example, the addition of a little salt will sharpen it. If this is done, a loose woven sack filled with salt and suspended in the tank, will be found most convenient. Place a resting rack across the top of the tank, arranged. at sufficient depth so that the impressions on the face of the die will be well covered with water when the die is laid on it. On flat surfaced dies or on dies in which the impressions are shallow, a depth of from 1 to 1½ inches is about right.

When all is ready get the piece out of the fire. If there are any dangerous looking corners or sharp projections that do not need to be hard, partly cool them off with a water jet or piece of water soaked waste to prevent chipping. · Place the die on the resting rack face down and turn on the water. If the piece is wide or flat, prevent warping or crowning by keeping the back slightly cooled off; just enough water and no more. Run the hand over the face frequently to find how it is cooling off.

Never let a die cool off entirely in the water. Whenever the face is cool enough to prevent the temper from drawing, get it out as quick as possible and lower it into the oil tank. Keep the die moving or agitate the oil.

The temper should be drawn slightly on all hammer dies, both to relieve strains and to give them resiliency or spring, as well as for better wearing qualities, and the drawing should be begun immediately; even before the die is quite cooled off. If there is an oil tempering furnace at hand large enough, get the piece into it. Raise the temperature to around 400 degrees Fahr. and hold it there for an hour or so. If for any reason this method cannot be used, swab the die with light machine oil and place in a furnace partly cooled off. Leave it there until the oil begins to flash, then remove and allow it to cool off in the air.

A die should never cool off entirely in the water. When a mass of steel at the hardening temperature is plunged into cold water, the grains

in its outer surface immediately become set and rigid. A certain amount
of contraction and shrinkage also takes place, partly because of the change
from high to a low temperature and also because of the hardening of the
metal. The amount of this shrinkage is in exact proportion to the sur-
face area of the mass being treated; the greater the area the more the
shrinkage. If this change took place all the way through there would be
no trouble; but it does not. In the first place, the interior of the piece
cools off much more slowly than the outside and secondly, the setting
of the grains due to hardening extend in a depth of from only ¼ to ½
inch at the most. This suddenly chilled outer layer is consequently be-
ing forced against the softer mass inside with an enormous pressure, caus-
ing distortion and strains which become more marked as the piece cools
off. When the temperature recedes to a certain stage, governed partly
by the temperature of the quenching water and the air, a violent action
takes place. This is the danger point. The friction created by the mole-
cules striving to adjust themselves to the new conditions generates heat
inside; heat means expansion, and unless this condition is offset prompt-
ly by heat applied to the outside to relieve the strains, the die, particular-
ly if a large one, has about an even chance of bursting open. Whether
it does or does not, the strains are there and are just as liable to manifest
themselves in service later on as they are to appear immediately after
hardening.

Allowing the dies to remain, in the water too long and failure to
draw the temper promptly after hardening is responsible for considerable
breakage. This is partly due to the lack of proper equipment, and also
to the fact that the principles involved are not so generally understood
as they might be even among steel hardeners. This heat generation by
friction, or as some might call it, molecular reaction inside of a body of
steel, is no pet theory, but the author has noted its effects during many
years of close observation and practice in the heat treating of steel. Fur-
thermore, he believes it will be found in line with the natural laws gover-
ing cooling bodies. Be that as it may, the writer has found this method
of hardening dies a success and can recommend it to steel treaters who
are having trouble.

BLAST FURNACES AND THE MAKING OF PIG IRON
By Arvid Anderson*
(A Paper Presented Before the Hartford Chapter)

In producing steel from iron ore the manufacture of pig iron is the
most important intermediate step. In late years a number of men, for ex-
ample, Yates, Chenots, Ellerhousen, Broling-Lang, Cassett, Siemens, Blair
and a few others have tried to manufacture steel directly from the ore, but
these attempts have not met with any success and at present are only of
historical value.

The only practical method of manufacturing pig iron is by the blast
furnace; no man can really claim the honor of being the inventor of the
blast furnace, for as far back as the history of iron and steel goes the
manufacturer and furnaces in which he charged layers of fuel and iron
ore. The product of the first furnaces was only a sponge-like lump of more
or less pure iron and a large percentage of iron went into the slag.

*Pratt & Whitney Co., Hartford, Conn.

At the beginning of the fourteenth century an agreement was made between the European nations that a prisoner of war could be exchanged for another, or that the prisoner could be bought free. This brought about a labor shortage and the iron manufacturers had to look to some other source for power to drive the bellows of the furnaces. As a result their minds turned to the water wheel.

By installing the water wheels the bellows could be made larger and a more even pressure on the blast was obtained, which produced partly melted iron. The producers at first worried about this molten iron, noticing that the initial product was less and very hard and steel like, though after the refining process the final product was larger than by the old type furnaces. Thus, soon all furnaces as far as possible were changed over to produce molten iron. Where the first blast furnaces were really built is still a source of argument, but so far as known the first furnace was built in Sweden the early part of the fifteenth century, though Professor Beck claims that the first blast furnace was really built in Germany in the middle of the fifteenth century. In a deed dated 1431 the King of Sweden gave to one of his generals all the income from a certain blast furnace. The first furnace constructed after drawings was built in Sweden in 1573 and was only 10 feet in height.

At the beginning of the sixteenth century this method of manufacturing iron was used only in Sweden, the western part of Germany and the eastern part of France. When the blast furnace first came to Belgium is still unknown although after Carl of Burgund lost in battle in 1496, he gave orders to his soldiers to destroy all blast furnaces. In France this method became general after Carl XI called in men from Germany to build furnaces. The first blast furnace in England was also built by Germans in 1540 for the manufacture of guns and ammunition. In the United States the first furnaces seem to have been built in the early part of 1700.

Blast furnaces can be divided into two classes, charcoal and coke furnaces. The charcoal furnace is little used in the United States. Of about 465 furnaces operating in this country a year ago, only 40 were charcoal fired, and in 1916 there was produced in this country about 39,000,-000 tons of coke pig iron as compared with only 370,000 tons of charcoal pig iron, this showing that charcoal blast furnaces are of little interest to the people of the United States.

The modern blast furnace consists of a tall cylindrical stack lined with an acid fire brick and built on a very deep and solid foundation of stone and fire brick. The American type of furnace ranges from 80 to 100 feet in height. The stock or furnace proper which is usually round consists of three divisions. At the bottom is the hearth or crucible, cylindrical in shape and about 8 feet deep; above it is the bosh, about $12\frac{1}{2}$ feet high, whose diameter flares out from that of the hearth about 16 to 22 feet making it the largest inside diameter of the furnace at any point. From the top of the bosh the walls converge gradually to the throat which is the very top of the furnace. The entire furnace is usually inclosed in a steel jacket and up to a certain point by cooling plates of bronze or other metal through which water circulates. Water is also sometimes allowed to flow down the outside of the furnace. The section above the bosh is supported on a mantle and column.

Through the lining of the furnace, just at the top of the hearth, extend the tuyeres, 8 to 16 pipes having an internal diameter of 4 to 7 inches through which hot air is blown to burn the coke and furnish the heat for the

smelting operation. The tuyere notches or openings through which the tuyere pipes enter and the tuyeres themselves are surrounded by hollow bronze rings in which cold water is flowing to prevent them from melting on the inside. The number of tuyeres and their size depend on the diameter of the bosh and the volume and pressure of the blast. It must be small enough so that the effect of the blast can reach the center.

On the side of the furnace and 30 to 40 inches below the level of the tuyeres is the cinder notch which is protected by a water-cooled casting. It is closed by forcing an iron plug into it around which the slag cools and closes up the opening. The slag must not be allowed to rise above the level of the tuyeres. In the front and at the very bottom level of the hearth or crucible is the iron tap hole from which all the liquid contents of the furnace can be drained. This is a large hole in the brick work and is closed by ramming in several lumps of clay.

The hottest part of the furnace is near the tuyeres and a few feet above them and at this point the most water for cooling is needed to prevent the brick work from melting. The brick work also is protected on the inside by a thin layer of deposited carbon caused by the effect of the strong reducing conditions present in the furnace. These conditions are due to the excess coke producing a deposit of finely divided carbon which in turn is covered by a cinder slag which sticks to it. This combination is effective in protecting the internal brick work.

At the top of the furnace and just above the throat is the charging arrangement consisting usually of two bells, a large one below and a smaller one above, each fitting in a hopper and so arranged that only one can be lowered at a time to prevent the escape of gas. Various devices are used to distribute the ore evenly in the furnace. This distribution is an important factor in prolonging the life of the lining of the furnace, the time required for melting and the quality of the iron.

The materials used in making pig iron are iron ore, fuel and flux. The ore is kept in huge piles in a yard and is handled by a large traveling crane. The cranes load the ore into bins from which it is run into small hopperbottom cars called larries, which are supported on scales for weighing. These larries dump the ore into buckets or skips which are hoisted to the top of the furnace up an inclined track and dumped automatically on the upper bell or into a hopper. The flux is handled in the same way while the coke is measured in cubic feet, the contents of a skip representing a definite weight. This method is known as skip charging. The old way was to weigh the materials in wheelbarrows which were raised to the top of the furnace by an elevator and dumped around the bell by hand. One complete charge of ore, coke and flux is called a round.

Gas generated is taken off at the top of the furnace through one or more openings connected with a large pipe called the downcomer pipe, which leads to a large chamber on the ground, known as the dust catcher. In this device most of the dust which consists of a mixture of fine ore and coke together with a little flux is deposited. Here the direction of the gas is also changed. As a rule no water is employed but if part of the gas is to be used in gas engines, it must be purified by being lead through a chamber, where it is sprayed with water and passed over moistened bricks. The heating value of the gas, however, is low—85 to 100 B. t. u. Only about one-third of the gas is necessary to heat the blast and the rest may be used for power.

The top of the furnace often is provided with a number of counter-weighted doors, called explosion doors, which open automatically to relieve any excessive gas pressure. In some cases, however, these doors are omitted and the top so designed as to have sufficient strength to withstand an explosion. A door which can be opened from the ground to relieve gas pressure is called a bleeder. In early practice the gas was allowed to escape into the air and burn, being led away from the charging hole by a chimney in order to protect the workmen at the top of the furnace.

The air blast used in blast furnace operation is heated by passing through stoves. These stoves are cylindrical in form, up to 100 feet high and consist of a steel or iron shell lined with fire bricks which form a number of flues or passages. Depending upon the number and the arrangement of the flues, they are known as two-pass, three-pass stoves, etc. They are regenerative in principle, gas being introduced and burned at the bottom, the products of combustion going out at the top. When a stove is hot, the blast is forced through in the opposite direction, the two operations occurring alternately. A large furnace generally has four stoves, three of which are being heated by gas at one time, while the fourth is heating the blast.

Another operation on the blast is drying it. This is accomplished by passing it over pipes in which brine at a temperature of about 32 degrees Fahr. is circulating, the moisture being deposited on the pipes as ice. The heating and drying of the blast are two of the most notable strides in advancement in blast furnace practice.

The hot blast increases the temperature near tuyeres and localizes the combustion, thereby requiring less air. The upper part of the furnace is cooler and the gases carry off less escaping heat, thus cutting down fuel consumption and increasing the yield of the furnace. Drying of the blast prevents 100 to 500 gallons of water from entering the furnace per hour and results in considerable increase in efficiency and fuel economy.

The blast is driven into the furnace by immense blowing engines similar to air compressors but much larger. These engines run up as high as 2500 horsepower each and are capable of compressing 50,000 to 65,000 cubic feet of air per minute at a pressure of 15 to 30 pounds per square inch. It requires about 4 to 5 tons, approximately 100,000 cubic feet, of air per ton of iron produced. Alternate layers of fuel, flux and ore fill the furnace down to the top of the smelting zone, the location of which depends upon the volume and pressure of the blast, size of furnace, etc. The fusion or smelting zone extends usually, however, from the level of the tuyeres to a few feet above them or about to the top of the bosh. It takes about 15 hours for the material to descend from the top of the furnace to the bosh. During this descent the material is held up by the uprushing column of hot gases, the friction of the load on the walls and by the loose column of coke which extends through the smelting zone to the bottom of the furnace. Coke alone of all the material resists melting in the intense heat of the zone.

The blast entering the furnace through the tuyeres consists of 23 per cent by weight of oxygen and 77 per cent by weight of nitrogen. The nitrogen is chemically inactive and does nothing except to absorb heat in the smelting zone and lose it at higher levels. The oxygen attacks all the coke in the smelting zone and some of it below the tuyeres to produce a great volume of carbon monoxide gas (CO) and a temperature of 3000

degrees Fahr. or more. The hot CO and nitrogen pass up between the particles of solid matter, to which they give up the greater part of their heat although the CO also reacts chemically with the iron ore.

At the top of the furnace the following reactions take place between the ore and the gases:

(1) $2Fe_2O_3 + 8CO = 7CO_2 + 4Fe + C$

(2) $2Fe_2O_3 + CO = 2FeC + Fe_2O_3 + CO_2$
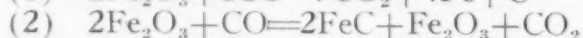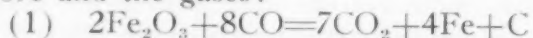
This action continues with increasing rapidity as the material becomes hotter. The carbon formed in the first reaction deposits like lampblack on the ore. The carbon dioxide gas (CO_2) opposes those two reactions as follows:

(3) $Fe + CO_2 = FeO + CO$

(4) $C + CO_2 = 2CO$
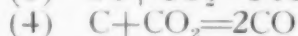
The third reaction begins at 575 degrees Fahr. which is at a point only three or four feet below the top level of the stock and the fourth begins at 1000 degrees Fahr., or 20 feet below the stock line. The latter is so rapid that the deposition of carbon ceases at 1100 degrees Fahr. All the way down the ore is constantly losing oxygen to the gases. Above 1100 degrees Fahr. FeO is stable but practically all of the Fe2O₃ has been reduced.

(5) $3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$

(6) $Fe_3O_4 + CO = 3FeO + CO_2$
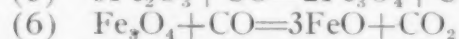
The deposited carbon has also helped to reduce the oxide of iron.

(7) $Fe_2O_3 + 3C = 2Fe + 3CO$
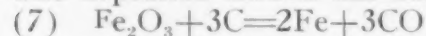
At 1300 degrees Fahr. the solid carbon begins to reduce the resistant FeO.

(8) $FeO + C = Fe + CO$
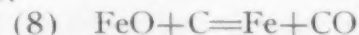
Practically all the iron is reduced to a spongy metallic form by the time the temperature of 1475 degrees Fahr. is reached. This is about 45 feet from the top stock line and less than 30 feet above the tuyeres. At this heat the flux is beginning to be decomposed by the heat, and only the oxide CaO comes to the smelting zone. The foregoing equations show the general reactions that occur.

In the first 15 to 20 feet of stock the oxides of iron $Fe_2O_3 + Fe_3O_4$ are converted to FeO by CO gas forming CO_2 gas, which is in turn partly reduced by metallic iron and carbon, as shown by reactions 1, 3 and 4.

From 20 to 35 feet below the stock line is the region of FeO being converted into metallic iron sponge by the carbon and CO, and the flux losing its CO_2. From 35 feet down to the smelting one is the region of metallic iron. The spongy iron absorbs carbon which lowers its melting point.

Upon reaching the smelting zone the iron melts and trickles down over the column of coke from which it completes its saturation with carbon. Here the flux unites with the coke ash and the impurities in the iron ore to form a fusible slag which also trickles down and collects in the hearth.

During this transit the different impurities are reduced by the carbon and the extent of this reduction determines the characteristics of the pig iron, since all the reduced elements are dissolved by the metal and the oxides by the slag. Only one exception is noted. Iron dissolves its own sulphide, FeS, and also manganese sulphide, MnS, to a lesser extent.

A large amount of silicon always is present in the coke ash and some of it is reduced.

(A) $SiO_2+2C=Si+2CO$
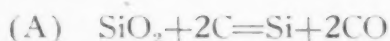
The extent of this reaction will depend on the length of time the iron requires to drop through the smelting zone, the amount of carbon tending to reduce it and the ability of the slag to take up silicon. A slag with a high melting point will trickle down sluggishly through the smelting zone causing the iron to do the same and thus allowing it to absorb considerable silicon. A higher heat in the smelting zone promotes the reduction of silicon and this can be controlled by the blast. By increasing the amount of coke in the stock, more chance for the reduction of silicon is given through the presence of the excess reducing agents and the excess heat.

Sulphur enters the furnace with the fuel in the form of sulphide of iron (FeS) and iron pyrites (FeS_2). FeS will dissolve in the iron unless converted to sulphide of calcium CaS by the flux.

(9) $FeS+CaO+C=CaS+Fe+CO$.
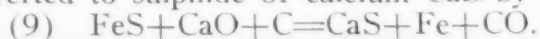
The CaS passes into the slag.

From the above equation, it is evident that excess reducing agent and high temperature which give silicon products low sulphur. In all cases it is true that iron high in silicon probably will be low in sulphur. The iron that runs especially hot in the blast furnace is high silicon and low sulphur.

Manganese is reduced by the following equation:

(10) $MnO_2+2C=Mn+2CO$.
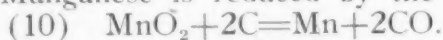
The amount of manganese in the iron depends mostly on the amount* in the ore, but a highly acid slag will carry some of it away. Phosphorus in the iron is directly proportional to the amount in the ore.

The chemical influence of the blast furnace is a strongly reducing one, which is necessary to reduce the iron from the ore, to get rid of the sulphur and to saturate the iron with carbon. Processes have been tried in which the reducing influence was not as strong but the sulphur in that case is not removed, and this is one of the most objectionable of all the impurities liable to be contained in iron. The high carbon in the iron makes it melt at a lower heat than purer metal and thus makes it easier to work with and handle.

Slag being of lower specific gravity floats on the bath of molten iron, and accumulates until it nearly reaches the tuyeres. The cinder notch is then opened by withdrawing the iron plug and piercing the skull of chilled cinder with an iron bar, and the slag drawn off to the level of the notch. This is done three times between each tap, about five hours intervening between taps.

The slag flows down an iron runner and into an iron ladle car, which is drawn away by a locomotive and the slag poured out on the slag dump. The amount of slag varies from one-half to two tons per ton of iron, depending on the purity of the charge.

After the last removal of slag, the tap hole or iron notch is opened by drilling with a heavy pointed bar. Out of the notch flows 100 to 150 tons of liquid pig iron, which carries about 30 tons of slag with it. A skimmer is situated about 15 feet from the furnace and is an iron and refractory plate extending almost to the bottom of the iron runner. This deflects the slag into a runner of its own and it is carried away to the slag ladle. The heavier pig iron flows under the skimmer and is carried away to brick lined ladles mounted on cars if it is going to the steel works, or is poured into iron molds at the pig casting machine or is run into sand molds.

SEE NOTE A

16	15	14	13	12	11	10	9	8	7

SEE NOTE C

30	29	28		27	26	25	24		23
43	42	41		40	39	38	37		36

SEE NOTE D

56		55	54	53	52	51	50		49
68		67	66	65	64	63			62

81		80	79	78	77	76	75		74
93		92	91	90	89	88			87

106		105	104	103	102	101	100		99
118		117	116	115	114	113			112

132	131	130		129	128	127	126		125
145	144	143		142	141	140	139		138

161	160	159	158	157	156	155	154	153	1

NOTE A—Price $300 each. All booths 10 x 20 feet. Rental price of Nos. 1-16 inclusive includes artificial gas and air from 1½-pound compressor. Each has a 2-inch connection from a 4-inch line approximately in the center of the booth. For the exhibitor desiring to furnish his own compressor, alternating current at 220-volts, 3-phase, 60-cycle will be furnished in place of air. All connections are made by the exhibitor. No extra charge for gas, air or current.

NOTE B—Price $300 each. All booths 10 x 20 feet. Rental price of Nos. 17-23 and 31-36 inclusive, includes power stubs in each. Current available is alternating, 220-volts, 3-phase, 60-cycle. All connections are made by the exhibitor. No extra charge for current.

NOTE A

| 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

SEE NOTE B

| 23 | 22 | 21 | 20 | | 19 | 18 | |
| 36 | 35 | 34 | 33 | | 32 | 31 | 17 |

NOTE D

| 50 | 49 | 48 | 47 | 46 | 45 | | 44 |
| | 62 | 61 | 60 | 59 | 58 | | 57 |

| 75 | 74 | 73 | 72 | 71 | 70 | | 69 |
| | 87 | 86 | 85 | 84 | 83 | | 82 |

| 100 | 99 | 98 | 97 | 96 | 95 | | 94 |
| | 112 | 111 | 110 | 109 | 108 | | 107 |

ENTRANCE

REGISTRATION

| 126 | 125 | 124. | 123 | 122 | | 121 | 120 | |
| 139 | 138 | 137 | 136 | 135 | | 134 | 133 | 119 |

OFFICERS ROOM

| 154 | 153 | 152 | 151 | 150 | 149 | 148 | 147 | 146 |

NOTE C—Price $210 each. All booths 10 x 20 feet. Rental price of Nos. 24-30 and 37-43 inclusive includes stubs for lighting circuit at 110-volts, 3-phase, 60-cycle, alternating current, or power for small motors not over 1-horsepower, alternating current, 2-wire, 220-volts, single-phase, 60-cycle. All connections made by the exhibitor. No extra charge for current.

NOTE D—Price $200 each. All booths are 10 x 20 feet. All booths in the central section included with the rectangle surrounded by the triple line are in the "Sunken Garden," 20 inches below the level of the surrounding floor space. No current is available for exhibits.

Several types of pig molding machines are used but the most common consists of a long series of metallic pans, carried on an endless chain. The iron is poured through a spout into the molds as they travel under the ladle. The iron chills quickly in the molds and when at the end of the machine, the solid pig is dropped into a car as the chain passes over a drum. The pig iron is now in a convenient form for transporting or storing. The molds travel back to the spout upside down and are sprayed with lime on their way back to prevent the molten iron from sticking. This method of casting is easier on labor and gives cleaner pigs, no sand being stuck to them.

The sand method still is used at some places and some foundry men prefer sand cast metal since they can tell by the fracture what grade of casting it will make. In this method, the cast house extends in front of the furnace and its floor consists of silica sand, in which impressions are made to receive the liquid iron. The main runner extends down the middle of the floor and either side is used alternately for casting. From the main runner the iron flows into secondary runners forming sows which feed the molds of pigs. After cooling the pigs are broken from the sows and both are taken away.

The blast furnace is by no means a perfect machine and numerous difficulties are apt to arise. The chief of these is localized chilling of the semimolten charge. This most often happens in the upper part of the smelting zone where a pasty mass attaches itself to the walls of the furnace. This hinders the descent of the charge and also deflects the gases to other parts of the furnace. Such a scaffold as it is called is liable eventually to stop up the whole furnace. It is often removed by shutting off the blast and allowing it to fall of its own weight, but sometimes it is necessary to cut a hole in the furnace and burn it out with a blow pipe. With fine ores the scaffolds or hangings are most liable to occur and sometimes result in slips which cause explosions.

Sometimes material freezes over the mouths of the tuyeres and must be broken or burned away. Also the metal may freeze in the lower part of the hearth and make it impossible to open the iron tap hole. It is then necessary to drill a new hole. These difficulties all affect the quality of the product more or less.

The method of calculating the blast charge is interesting and important but we have not the time to go so far into detail. Electric furnaces for smelting ore to pig iron are being experimented upon extensively and there are a good many in operation in the Scandinavian countries.

FATIGUE BREAKDOWN IN AUTOMOBILE STEELS
By John Miller*

(A Paper Presented Before Buffalo Chapter)

One of the most troublesome problems with which the automobile engineer has to deal is that of localized stress. Some one has said that the Lord gave us shafts, but the Devil put the keyways in them. Keyways, splines and other sudden and sometimes unavoidable reductions of sections may cause, in service localized stress from which fatigue fractures often result. The crystal grains at these points are deformed or moved more than elsewhere and if the stresses are intermittent or repeated, the to and fro movement gradually loosens the crystals and a slow or creeping crack travels through the section. This action in soft steels has been studied by different investigators using the microscope. It formerly was thought that the metal crystallized but this is not so. The crystals are there to begin with and the repeated loads destroy their cohesion.

There are certain steels and heat treatments which are specially suitable for resisting certain degrees and kinds of repeated stresses. Localized stress can also be reduced by proper design, such as providing large fillets and absorbing shock by allowing flexure on the member or a connecting one.

The metallurgist and engineer working together are finding more efficient methods for the utilization of heat treated steels and aluminum alloys. The writer believes that in a few years, we will be building cars of one-half the present weight and carrying the same useful load with more all round comfort and convenience. In building lighter cars we will need to take more care with the heat treatment of the parts and we will require more information about their fatigue resisting properties.

The engineer's most valuable guide in designing parts, is past experience. Mathematical calculations help a great deal but it is sometimes difficult, if not impossible, to estimate correctly the stresses which many complicated sections on an automobile have to withstand.

The strength of heat treated steel depends on its resistance to permanent deformation and on its resistance to complete fracture, after deformation, has begun, or in simple terms, on its hardness and toughness. These two properties are very usefully indicated by two simple tests, the brinell test and the notched impact test.

The elastic limit is a figure used by engineers in their calculations and is a good test for resistance to permanent deformation, but it is difficult to determine accurately. The brinell test, when properly applied on heat treated steel, bears a close relation to the apparent elastic limit. From the reduction of area and elongation in the tensile test, we get some idea of the toughness of the steel, but the notched impact in combination with a brinell test is much more useful. It can detect brittleness, where the other tests do not. Sometimes, however, all the different physical, chemical, thermal and microscope tests are none too many.

Resistance to deformation or hardness, appears to be the most important property to have in steels for resisting fatigue breakdown in automobiles. Unfortunately, great hardness is usually associated with

---

*Metallurgist, Pierce Arrow Motor Car Co., Buffalo.

lack of toughness, a certain amount of which latter is necessary. In a very hard piece of steel not case hardened there sometimes appears to be very high internal stresses and if put into a machine in this condition, these stresses added to those received in operation might soon result in failure. To remedy this, we draw or temper the hardened steel. This reduces the internal stress and gives it toughness, but it also reduces the hardness. How much toughness we should have is the cause for argument. Really it requires careful judgement and an intimate knowledge of the work the piece is expected to do, the properties of steel and the methods to be used in manufacturing the piece.

The writer has been experimenting with a Stanton fatigue testing machine, as shown in Fig. 1, and the results, appear to confirm opinions, which he has formed from results obtained in actual practice.

This machine uses a test piece ½-inch in diameter, 6½ inches long. It has a groove of 0.05-inch, turned centrally between the two points of support. The latter are 4½ inches apart. The repeated stress is obtained by a hammer weighing 5½ pounds. This is raised to a selected height and allowed to fall on the test piece, striking it in the middle, first on one side, then the test piece is rotated half a revolution and it gets a blow on the opposite side. This gives an alternating and localized stress at the bottom of the groove which has a small radius. The rate is 100 blows per minute and when the specimen breaks, an automatic switch stops the machine. A counter registers the number of blows. The fracture looks very similar to the fatigue fractures seen on a broken steering knuckle spindle. On the same material, fairly uniform results are obtained. The machine is quite useful for comparing the fatigue resisting properties of different metals and heat treatments.

The correct method for making fatigue tests is to take the same material and run three or four tests using a different intensity of stress in each case.
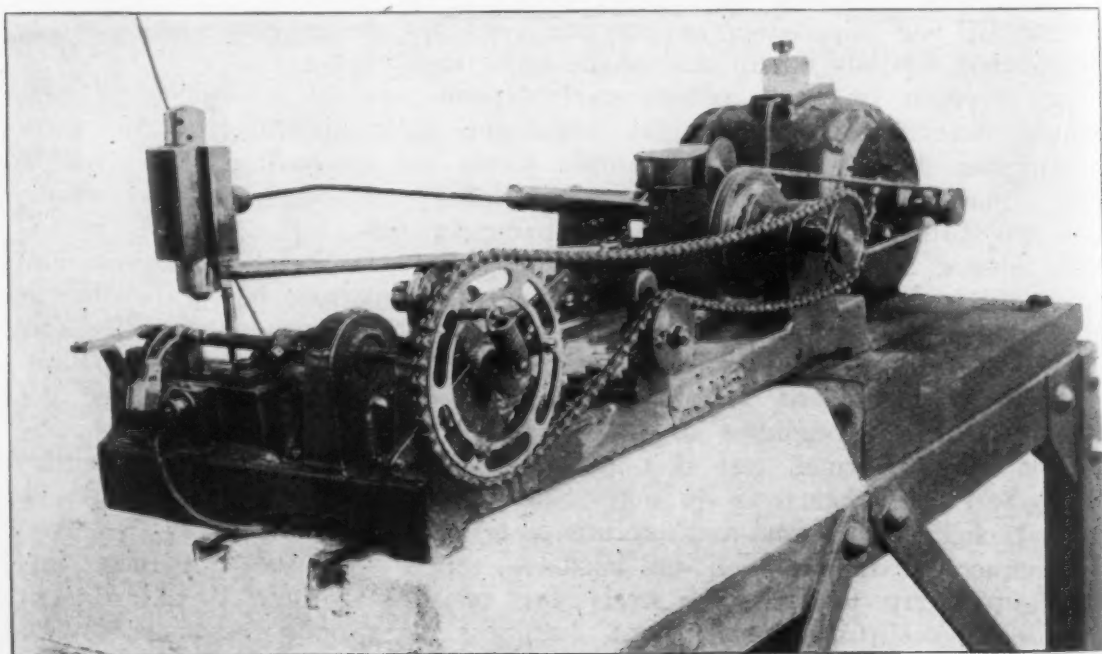

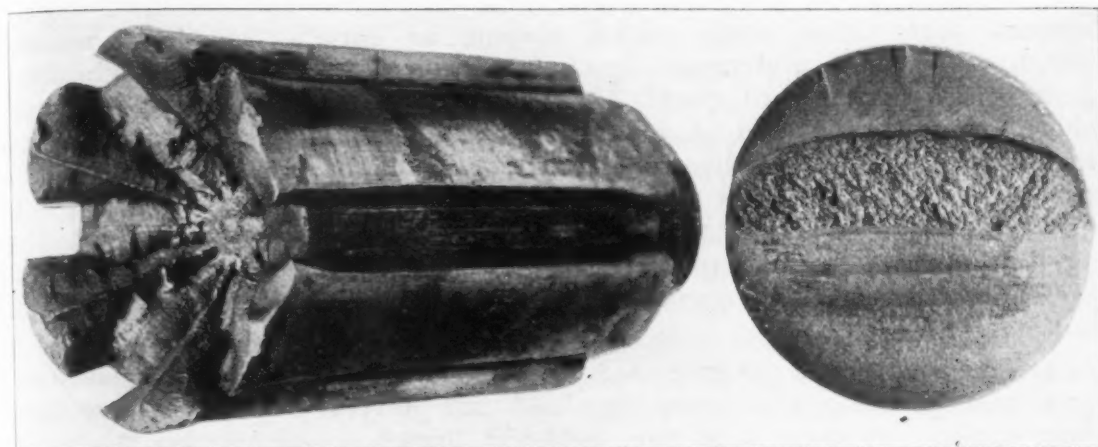Fig. 1—A View of the Stanton Fatigue Testing Machine

Fig. 2 (At the left) Shows the Fatigue Fracture of a Splined Steel Shaft.
Fig. 3 (At the right) Shows a Photograph of the Fatigue
Fracture of a Steel Steering Knuckle

If a curve is plotted, stress against number of blows, the behavior can be shown clearly. In the Stanton machine, a different stress can be obtained by using any fall up to 3.5 inches. On steels, useful results are obtained in a short time, from 10 minutes, to 1 or 2 hours according to strength, by using a 2-inch fall.

A piece of soft untreated steel, as example 0.20 per cent carbon screw stock, ½-inch diameter, will break after about 1500 blows. If quenched in water from 1650 degrees Fahr., it will stand 3000 blows. A piece of 3 per cent nickel steel, 0.20 per cent carbon, ½-inch diameter cold rolled, brinell 207, withstood 3500 blows. A piece from the same bar was quenched from 1500 degrees Fahr., in oil, brinell tested 387 and withstood 11,328 blows before it broke.

It is unusual for heat treated alloy steel to withstand much more than 10,000 blows with the 2-inch fall. Most of the different alloy steels properly heat treated in different sizes from ½ to 2½ inches thickness with a brinell hardness of from 248 to 302 give Stanton tests from 6000 to 8000. When treated to 302-418 brinell, we may get from 8000 to 12,000.

As the hardness increases above about 400 brinell or about 65 scleroscope, the steel does not stand up so well under the same height of blow. Most alloy steels, with 0.30-0.50 per cent carbon, hardened to about 500 brinell, last only about 2000 blows. Plain high carbon steel with this degree of hardness lasts about 500 blows. A steel with 0.20 per cent carbon and 3.5 per cent nickel quenched in oil from 1500 degrees Fahr. and not drawn, brinell 418 withstood 11,000 blows. Using much lighter blows, 0.5-1 inches the harder steels would not show such apparently poor results.

There are some parts of cars and trucks which under severe conditions receive shocks resulting in localized stress which must be about as much as the localized stress of the Stanton test using a 1-inch blow or even a 2-inch blow. With a 1-inch blow, the stress seems to be about 70,000 pounds and with a 2-inch blow, about 90,000 pounds per square inch. It is almost impossible to calculate it correctly.

It is usual in the best automobile practice to use for the more highly stressed parts, alloy steels, nickel chrome or chrome vanadium according to individual preference, quenched and drawn before machining. to a brinell hardness of about 248-302. This is as hard as can be machined economically and it gives a good combination of hardness and toughness. Full floating live axle shafts generally have a longer life under hard use if treated after machining to give 302-418 brinell. For this hardness on large sections, a fine grade of steel is necessary. If the steel is of poor manufacture, or not heat treated properly, the internal pressures arising from quenching may, combined with service stresses, cause failure.

Springs are treated to give 375-444 brinell. Oil tempered transmission gears which must have great hardness to prevent surface fatigue and deformation, are treated to give 444-532 brinell.

The writer has examined a great many parts of cars and trucks which have seen hard use and has noted that the ones which have given good service, have usually been hard with a good toughness. Parts which have failed by fatigue and where the design is not at fault usually show up soft under the brinell and sometimes they are brittle. Occasionally there are flaws in the material. One thing which has impressed him is that case hardened parts seldom fail by fatigue. When they do, it is usually because the hardness or depth of the case is not great enough. Sometimes places are left soft in order that they can be straightened or machined. Slow fracture can then occur comparatively easily. The writer has found that case hardening often will greatly increase the life of a highly stressed part when all other treatments fail. On rivet sets for pneumatic hammers, nickel and nickel chrome steel case hardened all over has given good results. On a large steam engine, a mild steel 1-inch bolt locking the connecting rod bearing would fail after running a few days. A nickel chrome steel heat treated to 364 brinell lasted about a month. A bolt made of nickel steel and case hardened lasted 2 years. Case hardening gives a high elastic limit where most useful to the outer fibres or crystals and toughness to the core.

Experiments on the Stanton machine indicate that 3.5 per cent nickel steel with 0.20 per cent carbon, carbonized 0.04-0.06 inch and quenched in oil from a temperature high enough to break up the cementite network and not drawn, gives results difficult to surpass with any other steel or treatment, which has been tried. For instance, a 3.5 per cent nickel, 0.20 per cent carbon steel with a 0.06-inch case, quenched from 1500 degrees Fahr. in oil, withstood 30,000 blows using a 2-inch fall. Using a 1-inch fall, other conditions the same, it withstood 300,000 blows. The best result obtained with steels not case hardened with a 1-inch fall was only about 50,000 blows. The life decreases when the depth of case is less than about 0.035-inch. It also depends on the hardness and toughness of the core this should be about 302-418. Drawing or tempering so that the case can be filed decreases the life. Using a double quench to refine the case also gave lower results.

The only reference to the fatigue resisting properties of case hardened steel which the writer has found is that in H. Brearley's excellent work on "The Case Hardening of Steel," which says, "One of the main objects of case hardening is to produce an article with a soft flexible core that

shall withstand sudden stresses or repeated vibrations, without developing cracks."

It would seem that very few engineers specify case hardening, unless they desire a very hard surface, which has to resist wear and they wish to avoid the brittleness associated with hardened high carbon steels. When they want a strong material they specify heat treated medium carbon alloy steel. There are several reasons for this. First, they may not know that case hardening has such fatigue resisting properties; second, the knowledge that the case hardening process, when not properly performed, sometimes results in reducing the strength by imparting brittleness; third, the risk of getting high carbon steel mixed with the proper low carbon stock; fourth, the treatment must be done after machining. Straightening a case hardened piece which has to withstand high stresses in use is not advisable; and fifth, case hardening costs more than plain heat treating. On the other hand, the value of the process and its success for highly stressed parts like the rear axle driving and differential gears, piston pins and vital parts like steering ball pins is widely recognized.

With improved methods of control we may see, in the future light car, case hardened steering knuckles, axle shafts, bolts and crankshafts case hardened all over. For parts like the front axle, case hardening would not seem suitable. A front axle should be fairly hard but also very tough and so that if bent in an accident, it could be straightened cold for slight bends, or after heating to about 1000 degrees Fahr. for bad bends. Other parts should be considered in a similar manner. Under loads beyond their capacity vital parts should be protected by allowing the shock to be absorbed in a flexible member or by straining one which is not so costly to replace or repair.

A PRACTICAL AID TO THE TREATMENT OF STEEL
By W. R. Ward*

(A Paper Presented by Title at the Philadelphia Convention)

Frequently one has a piece of steel from which a tool, jig, fixture or some part of a machine is to be made. The composition, grade or making of the steel may or may not be known by the one interested in it. If it is a case of a well known grade of steel—by well known, I mean well known to the particular user—previous experience with it has made him familiar with its characteristics. However, if he is not familiar with the steel he has about three alternatives to choose from in handling it: To follow instructions given by others who sell or have used the particular steel; to find out in the usual long way by making objects of it and trying them out in practice; or to resort to a simple test easily performed by a mechanic in a short time. This test I will describe later.

Steels that are used mainly for well known purposes, frequently possess remarkable physical qualities making them adaptable to other than the conventional uses for which the grade of steel is supposed to be suitable.

*Mechanical and electrical engineer, Lyells, Va.

What does it matter if the composition of the steel is not what it is supposed to be, if it will function successfully in the work to which it is applied. The proof of the pudding is the eating. The proof of the steel is in the service rendered by it irrespective of composition, name, grade, cost, etc.

The test alluded to is called the Metcalf test, and is known to most of you, but probably very little used. The ordinary fracture test of a piece of steel can hardly be called a Metcalf test. Many of those fracture tests are made throughout the steel business. They give only one physical condition of the grade of steel at its particular treatment. The fracture may or may not be the best one the steel could give under the proper treatment, thus it is not a true or fair test.

In making a test bar of steel whose physical properties are desired under a great range of treatments, two should be made as follows: A bar of the steel is forged ⅝ inch square by 36 inches long, nicked around in in the center while hot, and broken when cold. The bars are next properly annealed, and then nicked with a hack saw in inch multiples on opposite sides, and stamped from 1 to 18. The bars are sometimes nicked hot and not annealed.

The bars then are ready for treatment. There is an advantage in using a hot nicked bar in that it is cheaper to prepare, and gives the fracture of the forged steel in the first fracture.

The bars are first preheated by placing one end in an oven type furnace raising the temperature to about 1400 degrees Fahr., allowing one end to protrude through the door far enough not to get hotter than 400 to 500 degrees Fahr. The hot end of the bar after having been thoroughly soaked, is then placed about 3 inches in a high temperature furnace, such as a high speed steel treatment furnace, until the end begins to "sweat." It is then run back and forth in the furnace so as to give a gradual range of temperatures from the melting point to the black end. The object of not allowing more than about 3 inches of the bars at first to enter the high temperature is to allow the end pieces to soak, and not to overheat the following ones. These pieces, being out side, cool off a little but would readily obtain the desired tapered heat when moved backward and forward in the intense heat later.

One of the bars so treated is plunged into spring water at about 57 degrees Fahr., and another in cotton seed oil at room temperature, about 72 degrees Fahr. After cooling, the bars preferably should be sand blasted especially the oil quenched one, so as to rid them of any dirt, oil and scale. It is hard to get the oil out of the notches, and the sand blasting does this as well as any method. If there is any trace of oil, the fracture will be spoiled.

The bars are then held in a vice, and the inch pieces broken off one by one beginning with the melted end as they break more easily from that end. If a machinist's hammer of given weight always is used, a comparison of test bars can be readily made as far as their physical strength goes by the relative ease or difficulty met with in breaking the standard length pieces. Vice marks on them, also indicate the relative strength of the pieces.

The pieces should be kept clean, and put in some suitable case to be studied later after all the tests thus have been prepared.

The objection that the temperatures of each of these fractures are not known may be raised, but this is not necessary for all of the pieces. The

temperature of the best fracture which is just above the upper critical point is desired, and can be found with a little practice in a few trials by using double length pieces of the same stock treating them in the same quench, but at the assumed temperature of the desired fracture. If your temperature is above or below, it will show up in the fractures.

Since this is generally the only temperature desired for a given grade of the steel is forged 5/8 inch square by 36 inches long, nicked around in or other objects are to be made of the grade of steel on hand. File marks, scleroscope and brinell readings of one end of each piece may prove of interest and value.

It would be difficult to find words to describe properly the different fractures from one end of the bar to the other. Beginning at the melted end, the fractures are very coarse crystalline, and taper down to a very dense, fine grain, then change abruptly to a tough, fibrous fracture, changing not so pronouncedly at this end as at the highly heated end.

Useful tools have been made by the writer from supposedly inferior grades of open-hearth steel through the treatment aid given by this test. A good cold chisel that chipped tool steel successfully was made from a common steel rail.

PROGRESSIVE FAILURE OR FATIGUE OF METALS UNDER REPEATED STRESS

By H. F. Moore*

If a freight car axle is subjected to a heavy overload, the ductility of the steel of which it is made allows it to bend. The axle is distorted, but actual rupture of the metal will not take place. Consider now the case when the loaded freight car is running. For every revolution of the wheels there is on every longitudinal fiber of the axle a complete reversal from tension, pulling action, to compression, crushing action. If failure occurs after the car has run many thousand miles, the action is entirely different from the bending action under a single heavy overload. Almost without warning the car axle snaps short off, and the steel behaves as if it were a brittle material rather than a ductile material. Such sudden failure under repeated loading is said to be due to fatigue of metals, and occasionally occurs in shafting, automobile parts, airplane parts, wire ropes, band-saws, steam and gas engine parts, and other parts of rapidly moving machinery.

The apparent change in the nature of metal which fails under repeated stress gave rise to the theory that under repeated stress some profound change took place in the very nature of metal, changing ductile metal to brittle. This change was spoken of as crystallization and it was supposed that under repeated stress, metal changed its structure from fibrous to crystaline, and as evidence the sharp crystal appearance in the fracture under repeated stress was brought forward.

In the latter years of the last century, various metallurgists began to use the miscroscope as a means of studying the internal structure of metals, and their work, especially that of the English metallurgists Ewing, Rosen-

hain, and Humfrey, showed that structure of metals is always crystalline either before or after repeated applications of load. They showed that the fracture under repeated stress was due to the spread of minute cracks, called by them slip lines, which extended completely through the crystals of the metal and which, spreading and uniting into larger cracks, acted similar to minute hacksaw cuts, gradually reducing the cross section of a machine part until it could no longer carry its load and suddenly snapped off, very much as a piece of iron suddenly falls off when cut almost in two by a power hacksaw.

The starting point for one of these minute slip lines may well be some point in the metal where a minute flaw exists, either in the shape of a flaw within the metal, or in the shape of a notch or sharp scratch on the surface. We think commonly that our mathematical formulas for figuring the strength of machine parts are exact, because they involve exact mathematical processes; as a matter of fact these formulas neglect thousands of minute actions which tend to destroy material. For example, they take no account of a cutting action where a shaft rests on the edge of a bearing. Under a single load, these minute actions are of no importance; their effect is so localized that no appreciable effect is produced on the deflection of a piece. If, however, the loading is repeated thousands or millions of times, then such a microscopic cutting action may start a crack, which under repeated stress will spread to causing final failure.

Any sharp discontinuity in metal, due either to a surface defect or to an internal flaw, greatly increases the stress in the metal over a microscopic area around it. This fact has been verified both by experiment and by mathematical analysis. As an example, it may be cited that the localized stress at the edge of a rivet hole may be as high as three times an average internal stress in the metal of a plate; the stress near the bottom of a sharp notch may be five or six times as high as a stress a few hundredths of an inch away from the notch. At the danger of wearisome repetition it seems worth while again to emphasize that these localized stresses are of negligible account for structural and machine parts subjected to few loadings, but may be of the greatest importance in the case of parts subjected to many thousands of loadings.

The problem of the designer and the metallurgist is to determine limiting conditions so that this progressive failure will not occur. The usual method is to make sure that no fiber in any part of a machine member is loaded beyond the elastic limit of the material by any load which will come upon it. The difficulty of applying this rule is twofold. In the first place, the determination of the true elastic limit of metal is a matter of a great deal of uncertainty. Delicate methods of measurement of stretch and careful methods of computation give an elastic limit lower, sometimes much lower than the value given by the ordinary commercial test. Some doubt exists as to whether actual material is perfectly elastic under any stress, no matter how small that stress is. Here again it should be noted that a slight inelastic action is of no account for a structure loaded but a few times. But under load repeated many thousands of times any damage due to slight inelastic action is cumulative and actually may cause final failure. In the second place it practically is impossible to figure all the small localized stresses in a machine member, especially in an irregular shaped machine member. Sharp shoulders or notches may cause localized stresses many times those which would be given by the ordinary formulas of mechanics.

This progressive spread of small cracks is offered as an explanation of the occasional failure of springs while under the action of light loads. At some time in its history a spring is subjected to a few heavy loads. These heavy loads start microscopic cracks and are not repeated often enough to cause them to spread far. However, these microscopic cracks are in themselves very sharp notches, and cause high localized stress under subsequent light loads with consequent spreading of the cracks and final failure. For a machine part subjected to repeated stress it may be necessary to know its history as well as the properties of the material in order to judge of its safety.

At the present time the most satisfactory method to determine the ability of material to resist repeated stress is to make acual tests of it under a great many repetitions. Over a year ago the joint investigation of fatigue of metals was organized by the National Research Council under the auspices of the Engineering Foundation, University of Illinois Experiment Station, and National Research Council and was given as its main problem, the study of the behavior of a number of common kinds of steel under repeated stress. Tests are carried for several specimens of each kind of steel to one hundred million complete reversals of stress.

The machine used for the greater part of the testing is, in principle, a car axle placed upside down. A circular specimen rotates in bearings and is driven by a motor; weights are hung on it at two symmetrical points along its length. The bearings used are all ball bearing so that friction is reduced to a minimum. The suspended weights set up bending in the specimen; compression along the top side of the specimen and tension along the bottom. When the specimen rotates 180 degrees, any given longitudinal fiber changes from compression to tension, a complete reversal of stress. A revolution counter gives the number of cycles of stress. The machine runs at 1500 revolutions per minute and operates day and night. A battery of 15 such machines now is in operation. In testing any kind of steel or other metal, tests are made on such a machine, using various weights. In this manner the number of reversals required to cause rupture is noted. It is found that there seems to be a fairly sharp limit of stress below which failure does not occur at one hundred million repetitions. Moreover, a curve plotted with stress as ordinates and numbers of repetitions for failure abscissas seems to be horizontal for this limiting stress. This stress is called the endurance limit of the metal, and is considered an index of the ability of the metal to resist repeated stress.

The quantitative statement of factors affecting the fatigue resisting strength of a metal cannot be given at this time, but certain qualitative indications may be noted. Those fatigue resisting strength of metal depends upon: (1) Its elastic strength; (2) its ductility; (3) probably the amount of initial stress left in it by heat treatment; and (4) its homogeneity of structure. Possibly still other factors enter. It is evident that high elastic strength would tend to increase the fatigue resisting qualities of a metal. The effect of ductility may be explained by the fact that at a small flaw in a piece of ductile material some stretching would be found with a consequent tendency to distribute the stress over more material than in the case of a brittle material. Initial stress would, of course, tend to start microflaws when a slight additional working stress was given. It might be noted that if an ordinary testing machine test is made of a piece of steel containing initial stress, the measurement of stretch would be taken over a considerable length of the

specimen and there would be a tendency for the positive and negative initial stresses present at different parts of the cross section to neutralize each other and thus to mask the first point of yielding of the specimen. This neutralizing tendency would not, however, prevent any initial stress from starting a crack when it was reinforced by a slight additional working stress. Inhomogeneity of a material is a source of weakness under repeated stress in that it permits the stresses to break down, first through the weaker constituents, and then through the stronger constituents because of the already started microflaws. Here again the ordinary tension test tends to give an averaging measurement of stretch, masking the first yielding of the weakest constituent.

Probably many cases of fatigue failure of machine parts are blamed on the material used, when they should have been blamed on the shape of the piece or on the surface finish. In conclusion, it is desired again to call attention to the great danger of starting microflaws at the root of sharp shoulders, notches, or rough tool marks on a piece. Good surface finish and generous fillets at shoulders are vitally necessary in a design of parts to be subjected to repeated stress.

TRUE ACTION OF CYANIDE IN CASE HARDENING STEEL
By G. R. Brophy* and S. B. Leiter*

(A Paper Presented at Philadelphia Convention)

Cyanide baths are in more or less general use throughout the industries as heating mediums for heat treating steel, but more particularly as a means for obtaining a very hard, superficial case for wearing parts. This hardness has been thought to be due to the absorption of carbon from the cyanogen radical, the nitrogen aiding the penetration of the carbon. Stoughton[1] says, "We may also use liquids containing carbon, such as potassium cyanide and potassium ferrocyanide. It would appear that the presence of nitrogen assists in the absorption of carbon by the steel, and for this reason the various animal and vegetable products mentioned are preferred to charcoal from purer materials. It is also common in some cases to introduce gases containing nitrogen such as ammonia into the receptacle where the cementation is being carried on."

As a result of the authors' studies, it has been found that the nitrogen of cyanogen is responsible for a greater part of the hardening than is the carbon.

Before going further with the discussion a brief review of the existing literature on nitrogen in steel will not be out of place.

For a bibliography of the important literature you are referred to a recent publication by G. F. Comstock and W. E. Ruder[2]. A few of the points pertaining to the present paper will be given.

A. H. Allen[3] states that nitrogen is present in all steels and gives a method for its determination. Nitrogen causes great brittleness in steel

---
*Metallurgists, General Electric Co., Research Laboratories, Schenectady, N. Y.
1. Stoughton, "Metallurgy of Iron and Steel."
2. G. F. Comstock and W. E. Ruder, "Chemical and Metallurgical Engineering," page 399.
3. A. H. Allen, Journal Iron and Steel Institute, No. 1, pages 181, 1880.

by being absorbed during heating to a red heat in an atmosphere of ammonia, and 0.5 per cent causes such brittleness that a bar dropped from 6 feet will break.[4]

According to G. I. Fowler[5], nitrogen exists in steel as Fe_2N and Braune states that possibly as Fe_5N_2.

Good steel was found by Harbord and Twynam[6] to contain from 0.006 to 0.017 per cent nitrogen, crucible steel containing considerably less.

H. Braune[7] found that nitrogen increased strength but decreased ductility; 0.045 per cent destroyed entirely the ductility of a 50 carbon steel; that nitrogen is absorbed in all metallurgical processes, especially under high temperature, basic slag and reducing conditions. He cites a case where nitrogen produced great brittleness in a hearth-iron made from pig iron coming from a blast furnace producing large quantities of cyanide.

J. H. Andrews[8] published the effects of nitrogen on the critical points and found that the points are suppressed by heating and cooling in ammonia and that in the presence of 0.030 per cent nitrogen the points are completely suppressed.

According to N. Tschischewcke[9], nitrogen below 0.05 per cent occurs in solid solution and cannot be distinguished metallographically; it then makes its appearance in annealed samples as needles until in the neighborhood of 0.20 per cent it appears as pearlitic patches. The brittle film of nitrogenized samples was found to contain 11 per cent of nitrogen.

Until recently it was impossible to distinguish between pearlite and the so-called pearlitic nitride patches, but while examining a sample of electrically welded steel, which had been etched with Stead's cupric chloride reagent, it was noticed that certain parts of the pearlitic patches were blackened, while others remained white.

The nitride needles were also blackened. This lead to the examination of many samples which had been treated with ammonia and others which there was reason to believe contained nitrogen in some form. Upon repeated applications of Stead's reagent, pearlite darkens but does not become black as does the nitride. Cementite remains white.

When cyanided steels were etched after this manner, it was found that cyanide patches could be distinguished readily from pearlite. This method of etching has been used in the microscopic study of the samples discussed in this paper.

Nitride in steel responds to heat treatment very much as does carbon[10] and the resulting structures may be mistaken easily for carbon steel structures. Annealing develops the needles and pearlitic patches as shown by Fig. 6. Quenching gives a martensitic structure, Fig. 3.

4.   H. N. Warren, Chemical News, Vol. 55, page 155.
5.   G. I. Fowler, Chemical News, Vol. 68, page 152, 1894.
6.   Harbord and Twyman, Journal Iron and Steel Institute, No. 2, page 161, 1896.
7.   H. Braune, Stahl and Eisen, Vol. 25, page 1195; Review de Metallurgy, page 497, 1905; Jeinkontorets Annales, Vol. 59, page 636.
8.   J. H. Andrews, Carnegie Scholarship Memoirs, Vol. 13, page 236, 1911.
9.   N. Tschischewcke, Journal Iron and Steel Institute, No. 2, page 47, 1915.
10.   W. E. Ruder, "The Effect of Nitrogen on Steel," Chemical and Metallurgical Engineering, page 399, 1920.
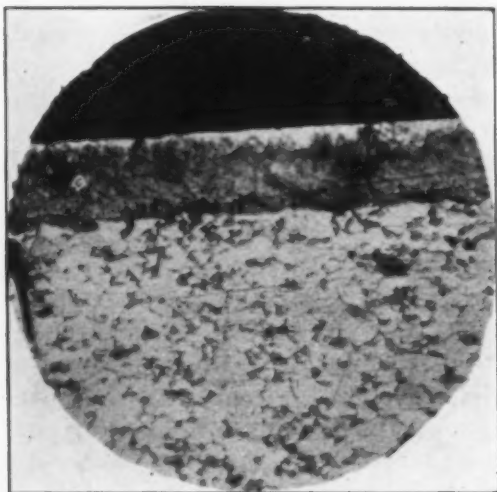
Fig. 1—Depth of Penetration x 100
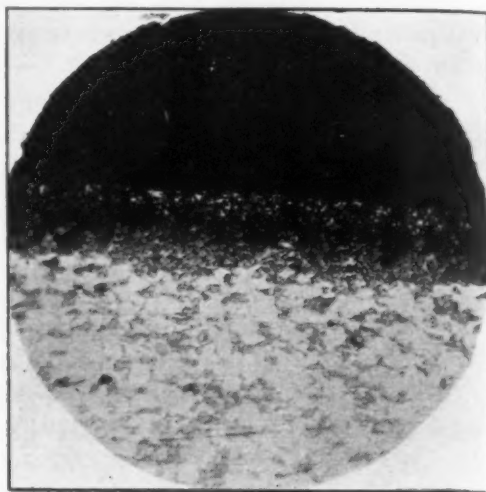
Fig. 2—Depth of Penetration x 100
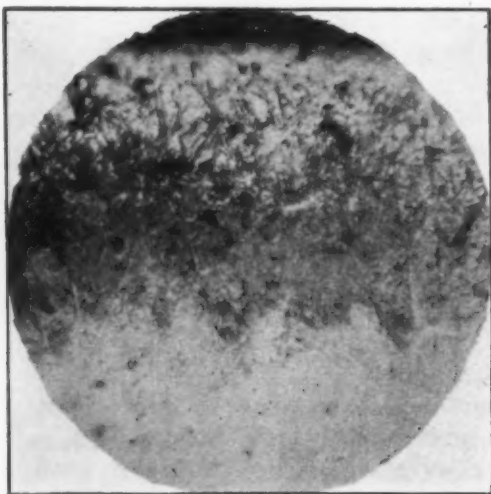
Fig. 3—Martensite x 250
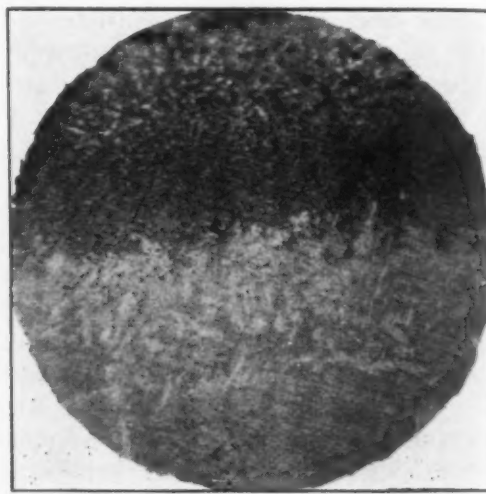
Fig. 4—Martensite x 250

Fig. 5—Martensite x 250

Fig. 6—Pearlite x 250

The case resulting from cyaniding and quenching from the baths is shown at low power in Figs. 1 and 2. Fig. 1 is low carbon steel heated 15 minutes in molten cyanide at 800 degrees Cent. and quenched. Fig. 2 is the same, but heated 30 minutes. The depth of penetration is the same in each case, but the concentration is greater and the diffusion better in Fig. 2.

Fig. 3 is iron, fired in hydrogen at 1000 degrees Cent. for 12 hours to burn out carbon, heated in cyanide 4 hours at 800 degrees cent. and quenched in water. The structure is martensitic.

Fig. 4 is the same as Fig. 3 but etched with Stead's reagent. Fig. 5 is the same iron heated one hour, quenched and etched with Stead's reagent. Fig. 6 is the same iron heated 4 times, quenched and then annealed at 900 degrees Cent., cooled slowly and etched with nitric acid. It shows nitride patches and needles. Fig. 7 is the same as Fig. 6 etched with Stead's reagent.

To prove the structures obtained in cyanided steels were nitrogen structures, a set of micrographs was kindly loaned by W. E. Ruder. These are of electrolytic iron, vacuum fused, nitrogenized by heating in an atmosphere of ammonia and variously heat treated.

Fig. 8 shows the characteristic nitride patches etched with nitric acid. These patches are easily mistaken for pearlite, although the laminations are not as fully developed. Fig. 9 shows the same patch etched with Stead's reagent, illustrating the differential action of Stead's reagent on nitride and carbon containing constitutents.

Fig. 10 is ammonia treated for 24 hours at 700 degrees Cent., reheated to 800 degrees Cent. and quenched in water. The needles have been retained in solid solution by quenching, but nitride appears at the grain boundaries somewhat resembling troostite in carbon steel.

Fig. 11 is electrolytic iron heated in ammonia for 24 hours at 700 degrees Cent., reheated to 700 degrees Cent. 15 minutes and quenched in water, reheated to 700 degrees Cent. and cooled slowly. Note the dark case resembling Figs. 1 and 2. The needles are characteristic of annealed nitride steels of lower nitrogen content and appear in the boundaries and slip planes of the grain. Ruder's work indicates that heating to at least 700 degrees Cent. is necessary to cause the appearance of needles.

Fig. 12 is the same material but quenched from 950 degrees Cent., followed by annealing at 950 degrees Cent. The grain has been considerably refined and the nitrogen of the case diffused greatly.

Analyses of the cases of steel rods originally containing 0.04 per cent carbon show an average of 0.33 per cent carbon after 4 hours heating in cyanide. This carbon content is not sufficient to cause the hardness attained by cyanided steel. A quenched 30 carbon is readily filed and has a Brinell hardness of about 207. A cyanided wire heated to dull redness and cooled slowly is still so hard that it is filed with difficulty, differing in this respect from a carbon steel. Therefore, it would seem that nitrogen is the hardening agent.

The brittleness imparted by nitrogen is illustrated by bend testing annealed cyanide wires after removing the case. The untreated material withstands 24 right-angle bends, while the annealed cyanided wires

stand but two bends before they snap. The reason for this is seen by examining Fig. 13, which shows the structure at the center of an annealed cyanided rod 3/16 inch in diameter.

The effect of cyanide and nitrogen on higher carbon steel has not been definitely determined as yet. However, it is known that nitrogen embrittles to a greater extent the higher carbon steels, even though refining the grain. A 50 carbon steel was heated 4 hours in cyanide, quenched and annealed at 850 degrees Cent. and cooled slowly. The case was very fine grained, showing a few needles on the interior. Evidently carbon retards the penetration of nitrogen.

Conclusions

Nitrogen has a greater effect in the cementation of steels by liquid carburizers than does the carbon.

Cyaniding greatly embrittles the steel treated and this effect is more or less permanent. Ordinary annealing does not restore ductility. Therefore parts resisting shock, even of small magnitude, should not be so treated for best results.

Solid organic matter, used often in carburizers, may have harmful effects.

Cyanide baths, as heating mediums in the best treatment of high grade steels and tools will cause brittleness which may decrease the life of the steel.

DISCUSSION OF MR. BROPHY'S AND MISS LEITER'S PAPER

MR. PATTERSON: I would like to ask Mr. Brophy if you can control the nitrogen penetration and keep it from making the core brittle in small sections.

MR. BROPHY: We have not tried to control it. I do not know that you can. Of course, the depth of penetration will depend upon the amount of ammonium or nitrogenous compounds present. We have not tried to control it any. On ¼-inch rods cyanided for twenty minutes we found nitrogen needles in the center; carburized in leather we also found needles in the center.

MR. PATTERSON: Is that true of cyanide hardening?

MR. BROPHY: Yes, we found needles present in the center in micrograph No. 13.

MR. ROCKWELL: I would like to ask Mr. Brophy about the physical properties of the iron nitride.

MR. BROPHY: It is very brittle. That is about all we know about it. Nitrogen raises the tensile strength more than the ductility. Perhaps Mr. Rouder can tell you more about that.

MR. ROUDER: Due to the difficulty of properly analyzing and getting a satisfactory analysis of nitrogen it is very difficult to say just what percentage has what affect on the steels. Generally speaking, however, the higher the carbon content the lower the quality of nitrogen necessary to make it very brittle. We have taken for example a very carbonaceous steel such as Mr. Brophy showed in the micrograph and nitrogenized it in ammonia, which is about the quickest way of getting nitrogen into the steel, and although as ductile as iron can be before being nitrogenized will, when we have this needle structure, be so brittle that you can break a ¼-inch rod

in your hand. According to the literature, I believe the limit for brittleness, as I remember it, given by some of the previous investigations, have shown that about 1-100 of one per cent of nitrogen in a 50 carbon steel, for instance, will make it too brittle for safety, and even 5-100 is necessary for making an ordinary mild steel brittle. But most of that work is rather indefinite. There has been considerable work done by several investigators on the affect of nitrogen on steel, but it has been my opinion that most of the metallurgists in general have looked upon that more as a theoretical consideration and have not given it a very serious thought for every-day work. This work done by Mr. Brophy shows that nitrogen is a thing to be dealt with in our every-day work and is itself practically, as far as he shows it, the real hardening agent in cyaniding processes.

MR. BROPHY: I have a note here from "Brown's Discussion of Nitrogen." It says, "Nitrogen increases the strength but decreases the ductility ." Nitrogen is absorbed in all metallurgical processes."

MR. McCLEARY: I would like to ask Mr. Brophy if there is a secession of the penetration after a given length of time in the cyanide bath. Your statement was that the needles occurred in the center of the piece and yet your general understanding in cyaniding has been that the hardening effect was not close to the center, in fact, confined to the extreme edge, possibly 0.005 or 0.010 of an inch.

MR. BROPHY: That is true; hardening is caused by nitride in the higher concentration of the needles. The concentration necessary to give the needle form of nitride will not give a hardening property.

MR. CLEARY: Have you noticed after a certain length of time in the cyanide bath, say a greater time than 15 minutes, that there was an apparent softening of the surface itself? In other words, what we have called a decarbonization?

MR. BROPHY: There is a loss of nitrogen on heating to high temperatures.

MR. McCLEARY: What I mean is this: that we have heretofore been familiar with using 10 to 15 minutes in the cyanide bath at about 1500 degrees and quenching in a cooling medium. A longer time than that has seemed to give us a decarbonized effect on the surface. The surface instead of being hard was apparently soft.

MR. BROPHY: Some of my samples shown were heated 4 hours in cyanide. In quenching they were still hard. There may have been some sort of an effect that we have not noticed. We are not interested immediately in the degree of hardness as much as we are in the effect, but the high concentration on the case itself, the depth, is not dependent upon the length of time heated.

MR. McCLEARY: Was there any copper plating on any of the pieces that were cyanided? I have noticed on copper plated pieces in solid carbonizers the same structure.

MR. BROPHY: No copper plating on any of those. Most of the samples were heated at a high temperature, at 1100 or 1200 degrees Cent.

MR. PATTERSON: May I ask what the affect of small quantities of nickel in the steel would be? We find that one-fourth of one per cent nickel in 10 to 14 carbon steel, heated 15 minutes in cyanide at 1600 degrees and
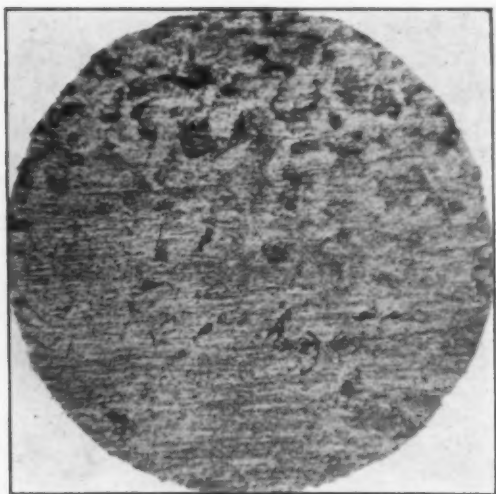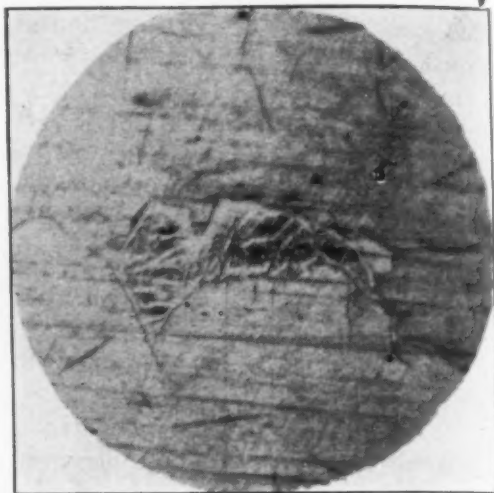
Fig. 7—Pearlite x 250
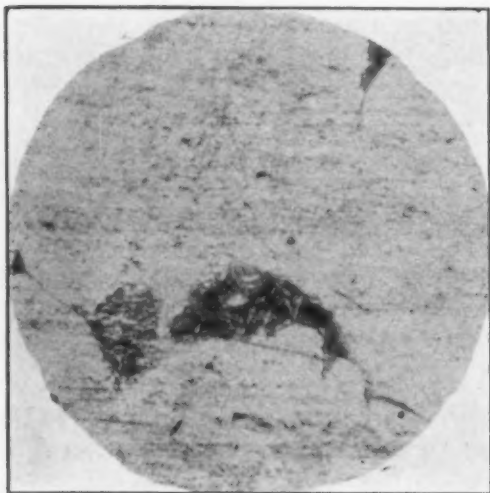
Fig. 8—Nitride Patches x 400
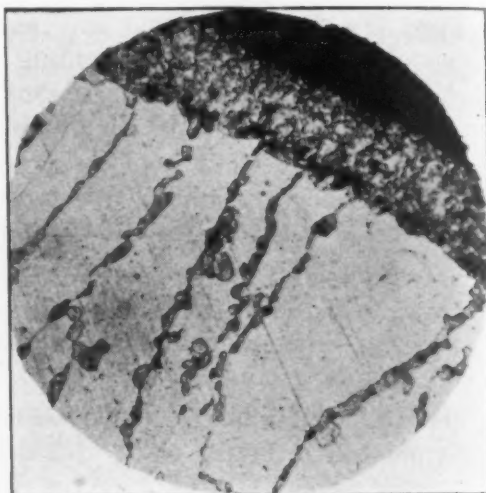
Fig. 9—Nitride Patches x 400
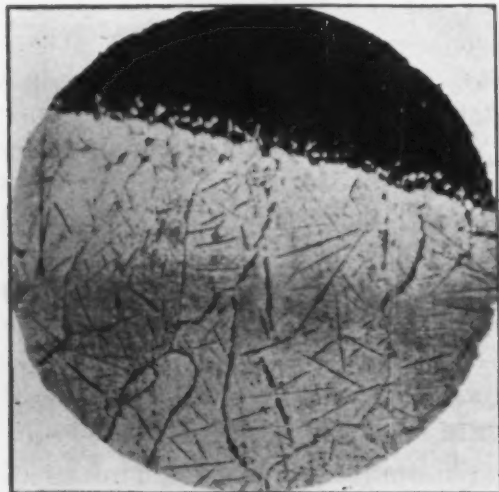
Fig. 10—Nitride Patches x 400
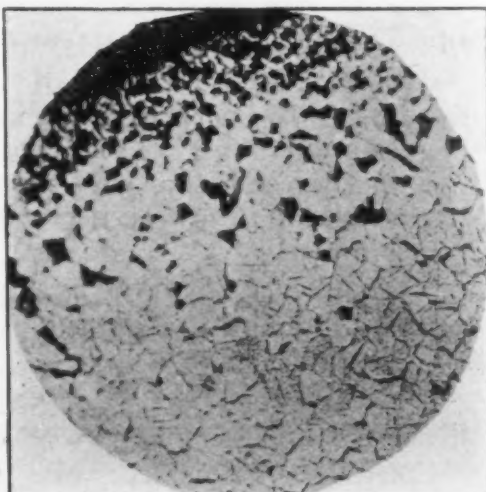
Fig. 11—Nitride Needles x 100

Fig. 12—Nitride Grain x 100
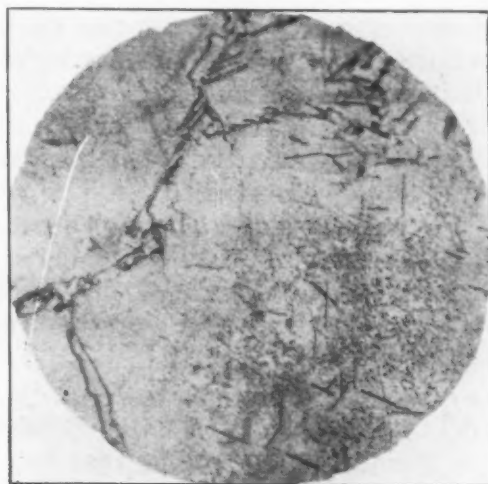
Fig. 13—Nitride Grain x 250

quenched in oil gives a case so hard it cannot be filed, and yet a shank on the tip which is about 0.10 inch in diameter can be bent 90 degrees before it will break. It seems to have a very tough core and we believe it is due to that nickel.

MR. BROPHY: Nickel may have some affect. A friend of mine carburized the specimens and we found no nitrogen present. We found nitrogen in almost all cases, but in this one particular case there was no nitrogen present. That may have been due to the fact it was an alloy steel. We have not investigated thoroughly an alloy steel.

MR. PATTERSON: What nickel content?

MR. BROPHY: That I do not know.

DR. HARTZELL: I would like to ask the vanadium content, if it contained vanadium, or what affect vanadium would have, if any, in checking the hydrogen penetration in a molten mass.

MR. BROPHY: I do not believe it would check the penetration. The vanadium would have an affinity for it in the solid steel. I will say off-hand that vanadium, if anything, would take it up faster.

DR. HARTZELL: Would it actually have any affect at all on the nitrogen in the cold steel?

MR. BROPHY: The vanadium nitride in the needle is similar to a so-called iron nitride.

MEMBER: I would like to ask if in the treatment of small watch parts you have found that in quenching them at about 1500 degrees after heating with cyanide, they became so brittle that you had to discard the cyanide method of hardening? We found that to be the case. From what I have learned in this paper it might be reasonable to suppose it is the nitrogen that has caused that to happen. Would you say that is a fact? The little pawl that causes the watch to tick and the little gears that cause the watch to run, in one of the lower priced watches, are all case hardened. They are made out of soft steel and case hardened. They work for years. When the manufacturers first started their case hardening they started it with cyanide, but they found they had so much trouble from breakage and the little teeth splitting off and little corners breaking on the pawl they had

to discard that method entirely. Are we to learn from this paper that that trouble has really been caused by nitrogen and not by carbon?

MR. BROPHY: I believe that is true.

MR. BURROUGHS: I would like to ask just what the concrete evidence is that the needle-like constituent is a high carbon? Would I understand that is a conclusion from your paper?

MR. BROPHY: No, we will call it nitride, because we have to call it something. It may be a cyanide, but we really do not know. There are evidences both ways. We tried some nitrogen determinations but they were not successful, and therefore when we met with no success there, we were led to believe it may not be a nitride.

THE APPLICATION OF FURNACE DOOR SCREENS
By Henry H. Wiegand*

(A Paper Presented by Title at Philadelphia Convention)

To discuss with steel treaters the terrific heat and glare that pours from a metallurgical furnace or oven, when the door is opened for charging or discharging, is needless. Everyone is familiar with its discomforts, but the majority has not been obliged to work close to these opened furnaces day in and day out as has the regular furnace attendant. It is for the alleviation of the lot of this man and thus to make his job more attractive and his output greater, that we will consider furnace screens.

When the door of a furnace on which the blast has been shut off is thrown open, the discomfort can be traced to three distinct sources; the convection heat, the radiant heat, and the glare.

The convection heat is due to the escaping of highly heated gases which quickly rise to the roof of the building, and are not so discomforting except to the man working close to the furnace. The radiant heat shoots out in straight lines and its intensity varies approximately inversely to the square of the distance from the source. This radiant heat is the main cause of the discomfort of furnace operators, which coupled with the glare that obeys the same laws, shoots out in a more or less horizontal shaft whose cross section is approximately that of the furnace opening.

Since man first began to employ an intensive fire, he has sought to protect himself from this heat and glare coming from an incandescent source. Although this endeavor has continued through thousands of years, yet it is only recently that marked progress has been made.

In the glass industry the earliest forms of protection were introduced. These consisted of sheets of iron which were suspended in front of the furnace; carried on the left arm like the shield of the Roman soldier, or born by a fellow workman, as the pavise of the archers of the Middle Ages. In the navy a stoker, to avoid punishment by the heat when cleaning fires, gets one of his fellows to hold a shovel between himself and the fire. All of these devices cut the efficiency of the operating force in half.

The immense growth of the steel industry with its fiercely heated furnaces, caused numberless efforts to be made to diminish the discomfort and danger suffered by the operators.

The most common form of screen used in this industry is the opaque sheet of iron which sometimes is fastened a short distance out from the

*Vice president, E. J. Codd Co., Baltimore.

furnace opening which it covers. The height of the bottom of the shield above the hearth is adjustable to suit the size of the work to be handled through the opening. This sheet iron screen is sometimes supported over head by chains or wires attached to either end. A hole sometimes is made in these screens for observation and for the introduction of tools. The swinging screen is said to have been used with advantage in some plants to facilitate the unloading into quenching tanks.

These opaque screens are useful on furnaces whose charges must be manipulated while under blast but their usefullness is seriously diminished if they become red hot; as the hot plate merely relays the heat originating in the furnace.

The life of screens subject to live flame is not great, as these soon warp and burn out. Sometimes liners are placed on the side of the screen to ward off the fire are to prevent the flames from impinging on the outside plate and also to minimize renewals. These screens usually are made of boiler plate. Perhaps if made of cast iron, they would not so readily take on a permanent warp, but they would be more liable to breakage unless made heavy.

Recognizing the necessity for viewing the interior of the furnaces, as well as protecting the men, a close mesh wire grating similar to a fly screen though made of very much heavier material, was substituted for the opaque sheet. This afforded visibility until the interstices became clogged with dirt and scale but penetrability was absent.

To prevent relaying of the heat brought directly to this type of screen, continuous streams of water frequently have been made to play over the screen which sometimes is tilted to insure better contact of the water with the heated surface. Such screens are usually made of boiler steel and unless supplied with the stream of water, warp and become more or less corrugated. The water then flows only in the valleys, and the ridges become sources of radiation. Another variety of water-cooled screens consists of a hollow box of thin sheet iron, which is fastened on the front of the furnace. A small stream of water is fed in at the bottom and passes out through an over flow pipe near the top. The top is open to avoid the danger of explosion through accumulated steam.

Screens cooled in this way add an appreciable burden to the factory overhead, as they consume an immense quantity of water and the presence of such a large chilled surface so close to the furnace demands more heat and consequent fuel. They also entail extra gears and fittings which require more or less skilled attention.

Another and serious drawback of the water-cooled screen is the increase in the moisture in the atmosphere around the furnaces due to the evaporation of the water. It is like turning a hot dry day into a hot humid one. As perspiration cannot evaporate freely in a wet atmosphere, the bodies of the men are not cooled in the way devised by nature and their efficiency is diminished.

None of the above forms of shields entirely cover the furnace opening, as being rigid and inflexible, a portion of the furnace opening must be left free for the entrance of the tools needed to handle the charge and of sufficient height to permit the charging and the discharging of the largest piece treated in the furnace. The main portion of the opening is covered by the screen, but the lower part continues to emit heat and glare.

An effort has been made to overcome the discomfort arising from this smaller opening by directing a sheet of air upward across the opening from a pipe perforated with a multitude of small holes. This helps to drive the convection heat upward behind the shield but has no effect on the radiant heat and glare. This adds another complication and additional cost to the overhead, for air under pressure is costly, besides it tends to cool the furnace itself.

A modification of this idea is contained in a furnace lately has been put on the market. This arrangement blows the sheet of air from above at an angle across the diminished opening onto the hearth, where this air mingles with the escaping convection heat that, by a special device preheats the air going to the furnace before it enters the furnace proper. This, like the sheet of air mentioned above does not affect the radiant heat and glare.

All the appliances heretofore mentioned are solid, opaque, cumbersome, and troublesome and while alleviating the trouble, do not serve the purpose fully. What was demanded was a door or shield which would permit a clear unhampered view of the interior of the furnace or oven; would not in any way interfere with the free manipulation of the tools required to handle the charge, yet a door that would keep the heat in and the cold air out. In other words, a door was required which should at the same time possess the qualities of opaqueness, transparency, flexibility and penetrability.

The nearest approach to this is the chain screen furnace door recently devised. The essential feature of this device is a sheet of chain composed of a multitude of freely hanging individual strands of small link steel chain suspended close together from a bar in a manner to form a continuous sheet or curtain of chain not unlike the familiar Japanese portiere. The single strands of chain give the penetrability and flexibility, the twisted metal composing the chain furnishes the opaqueness and the holes in the links of the chain produce the transparent effect. The closeness of the chain prevents free flow of the heat outwards or the cold inwards.

This curtain of chain hung before the uncovered opening to a furnace and resembling a coat of mail, effectively hinders the heat, glare, gases and sparks from leaving the furnace and the cold air from entering. These chain screens cover the entire opening down to the hearth, which the lower ends of the individual strands of chain just clear. Extended experiments made on furnace openings show, that while the radiant heat and glare come from all parts of the furnace opening, the convection heat flows out at the top and the cold air pours in at the bottom; so to prevent the chilling of the furnace it is necessary to keep closed the bottom as well as the upper part of the opening. Therefore, to save the heat and prevent the entrance of cold air, it is necessary to cover the whole opening, the bottom as well as the top, and this covering should lie close against the furnace front.

These chain screens are not to be considered as a substitute for the ordinary opaque door but merely as an auxiliary to be employed when the opaque door must be opened, or in those cases where the continuity of the operation compels the elimination of the ordinary opaque door. They do not keep all the heat in the furnace nor do they keep all the air out, but they materially decrease the losses. A great deal of the heat coming from the interior to the chains is reflected back and the cold air that does filter through the chains, keeps the chains relatively cool by robbing them of

their absorbed heat and enters the furnace preheated, thus saving heat that would otherwise be lost.

Experiments were made in order to obtain an idea of the effectiveness of this device in avoiding the losses arising from the opening of the opaque door. A thermometer was fixed on a standard at a point opposite the closed door and 10 inches distant therefrom, where it registered 110 degrees Fahr., as the temperature at this point when the ordinary door was closed. When this door was thrown open and the incandescent fire bed exposed, the thermometer rose to 400 degrees Fahr. On covering the furnace opening with the chain screen, the temperature at once dropped 265 degrees to 135 degrees Fahr., and the bare unprotected hand could be held anywhere in front of the screened opening without discomfort.

Photometric observations show the light and the glare of the bare fire are reduced about 85 per cent on covering the fire with the chain screen. The loosely hanging strands of light chain composing the chain screen with ease are parted and pressed aside by the tools or other objects projected into the furnace, only to fall together again and automatically close the opening when entrance has been effected.

Furnaces provided with these chain screens are charged, not only by thrusting individual pieces through the chains, but ore, fuel, coal and even shavings are thrown through the chains from a shovel. It is a common thing to see a boiler furnace being charged with fine bituminous coal through a chain screen without difficulty. The heat and glare are held back so effectively that the operator can work up to within five or six inches of the screen and can employ short length tongs and tools. This in itself is a great advantage as short tools are much handier and coupled with the cooler conditions at the furnace opening, enable the placing of the machines that are to operate on the heated metal close to the heating furnace, thus saving movement of men and metal, and shop space. Where the furnace charge is handled by means of tongs, the lower portion of each strand of chain often is replaced with light steel tubing. This prevents the chain catching in the crotch of the tongs. Where constant visibility is not needed, many screens are constructed with nearly the whole strand of tubing, only a short length of chain being placed at the top to insure flexibility and ready visibility. These tubular screens are impervious, yet retain the flexible and penetrable features.

Some electric furnaces whose contents caused a great evolution of fumes and heat have been inclosed with a circular screen of tubes nine feet long, each supported by a short length of chain from the edge of the hood that led to the stack. The furnace was thus encircled by a closed hood which could be freely entered or pierced at any point.

In factories where several furnaces demanding large screens are grouped together in a continuous line and not more than one is opened at a time, one or more screens mounted on an overhead track have been made to do duty for all.

Protecting shields, whatever their form have always greatly interested the safety engineer and have had his urgent advocacy, as he appreciates the ordeal undergone by the man whose duty holds him close to the furnace with its scorching heat. Many operators think only of the temporary discomfort, but effects follow which are slow in disclosing themselves.

Lately much attention has been directed to that insidious disease common among those whose occupation compels them to gaze at the glare emanating from incandescent materials, known to the medical fraternity as "Glass Blowers' Cataract." It is the general opinion that the universal employ- ment of screens would avoid this affection.

The same applies to the eye trouble experienced by those who work around electric furnaces, and which is indicated by a violent inflammation of the eye ball and a painful sensation similar to sand in the eyes.

Many manufacturers, aside from the economical advantages to be thereby gained, actuated by truly humanitarian impulses have endeavored honestly to alleviate the undesirable conditions about their furnaces and their glowing products by the liberal use of screens, with the result that the health and eyesight of thousands now are safe-guarded and the operators stimulated to increased production.

ANNEALING AND HEAT TREATING MISCELLANEOUS STEEL CASTINGS

By Charles N. Ring*

(Presented by Title at Philadelphia Convention)

The process of annealing or heat treating steel castings to obtain correct and satisfactory results properly begins with the metal production department. In order to obtain uniform results from the heat treatment of steel castings for specified classes of work, it is necessary that the heat treater receive uniform material with which to work. Heat treatment will not give to steel properties which it does not contain, but it does bring out or make available properties that are inherent to the steel.

The province of heat treatment is to bring the steel to such a per- manent or fixed physical condition that the inherent qualities of the steel can be utilized to the best advantage for the purpose intended. It therefore results as a corollary that, in order to secure the best results from the heat treatment of steel castings for specified purposes, it is essential that the heat treater be furnished with steel that contains in an inherent form the qualities that are necessary to obtain these results. The heat treating department and the metal production department should co-operate along these lines, and the production department strive to supply the heat treating department with metal conforming to specifications decided upon as the most desirable to obtain by heat treatment the results desired.

The first item to be considered by the steel treater is the chemical composition of the steel to be treated. The carbon content is naturally of the greatest importance, as indicating within approximate limits the temper- ature to which the steel must first be heated to reach the condition of solid solution and thus secure the finest grain structure of which the steel is capable. Manganese content is also important because of the bearing it has upon the strength of the steel and upon the ease or difficulty with which the steel will respond to a given heat treatment.

Phosphorus and sulphur content must also be taken into consideration because of the bearing these two elements have upon the strength and ductility of the finished product. Where a steel high in ductility is required,

*Chief Chemist, Ohio Steel Foundry Co., Springfield, O.

it is advisable to keep the phosphorus and sulphur content under the limit
of 0.05 per cent. The effect of sulphur within the limits of 0.06 per cent
is probably negligible in the finished product, but when over 0.05 per cent
it has a tendency to produce red shortness in the metal, or, in other words,
cause the metal to be weak when at or above a red heat. This weakness
of the steel at temperatures above a red heat may cause the casting to
crack because of the strains set up during the process of heating or cooling.

The effect of sulphur on steel when in the cold state is a much mooted
question, and probably depends to some extent upon the condition in
which the sulphur is contained within the steel. The tendency of modern
opinion seems to be, that if sulphur is contained in the form of man-
ganese sulphide, it has very little weakening effect upon steel in the cold
state, but, if in the form of iron sulphide it has a greater tendency
to weaken. Proper manganese content probably offsets any weakening
effect of sulphur within reasonable limits. What these limits should
be are at the present time under investigation by the American Society
for Testing Materials, the bureau of standards, the railroads, and the
steel manufacturers. When their report is submitted we shall probably
know more about it than we do at the present time.

Carbon and manganese content are also of prime importance be-
cause of the direct bearing they have on the strength and hardness of
the steel. There are numerous charts, formulas and data from which
the proper content of these elements can be calculated to obtain a given
strength or hardness. These charts, formulas, etc., will give approxi-
mate figures only, therefore to arrive at satisfactory results, experiments
guided by this information must be made at individual plants under
individual conditions.

Under conditions obtaining in a modern steel foundry, where pro-
duction is a factor of prime importance, it would obviously be impossible to
make experiments on each individual heat to demonstrate for which kind
of work that steel is best fitted, or to see what heat treatment would secure
the best results. The method to pursue is to group the different kinds of
work in the shop into classes, according to the specifications demanded.
The work in most foundries furnishing miscellaneous castings can be
placed in from three to four classes. Study of these classes separately as
to strength, hardness and ductility; figure the approximate chemical com-
position and the heat treatment required to obtain these results, and then,
guided by the conclusions, experiment on each class separately until results
are obtained from certain definite chemical limits and certain definite
heat treatment that satisfactorily meets the requirements. Then formulate
this chemical composition and this process of heat treatment that has given
successful or satisfactory results into data for a standard practice for that
given class of work. This standard practice should then be followed as
long as it continues to give satisfactory results. This is where the co-
operation between the heat treating department and the metal production
department should begin to function.

When that steel conforming to certain chemical limitations is secured
and subjected to certain definite heat treatment gives certain definite results
within the required physical specifications of one of the classes of steel,
inform the metal department that, when steel for this class of work is to
be made, it should be within the chemical limits as determined by the

experiments. Furnish the metal department with a copy of the chemical limitations and the class to which they belong. The metal department should then strive to furnish the steel to conform to these limits.

Another matter worthy of serious consideration is the condition of the steel received for heat treatment, aside from the chemical composition. Steel, in order to show the maximum results from heat treatment, should be as thoroughly deoxidized during the process of manufacture as is practical in average commercial work. The presence of a large percentage of oxides or inclusions of slag and sulphides may have a very serious effect upon the size of the ferrite network and crystal structure of the steel. The metal department should bear this in mind and adopt methods to thoroughly deoxidize, cleanse and quiet the steel before casting.

Having received at the heat treating department the proper kind of material with which to work, the success of future operations rests entirely with the heat treater, and, in carrying out this operation, there are many items to be considered, the first of which is the furnace used for heating the castings. There are a number of different types of furnaces in common use that give satisfactory service and the type to choose is, of course, controlled by the local conditions, but whatever type is used, it is of prime importance that it be so constructed and operated that a uniform temperature can be maintained at all times in all parts of the heating chamber. This uniformity of temperature is as essential during the period of bringing up to the required temperature as it is after the required stage has been reached, otherwise there will be a loss of time and fuel in bringing that part of the furnace which lags behind up to equilibrium with the other part of the furnace. This will also cause part of the charge to be held at the maximum temperature for a longer period than the balance which heated up more rapidly and does not conduce to uniformity of results. If the furnace does not reach a stage of uniformity as to temperature in all parts of the heating chamber and maintain this uniformity at the temperature required, its use should be discontinued and it should be reconstructed to eliminate this defect.

The fuel used for generating the heat in the furnace can be either coal, gas, oil or electricity, all of which give satisfactory results if properly manipulated. Where coal, gas or oil is used, care must be taken that the castings are not subjected to the direct action of the flame, or they will be badly pitted and oxidized. Electrically heated furnaces are subject to closer control and maintain a uniform heat with minimum care, at the same time reducing surface oxidation to a very low figure.

In charging a heat, care should be taken to charge in one heat only castings of similar design or thickness of section. Castings of intricate design and small sections demand particular attention in charging, drawing and heating, and where charged with castings of simple design and with heavy sections, complicate the operation. If heavy castings and light castings are charged in the same heat, the light castings will come up to temperature considerably before the heavy ones, causing a loss of time and fuel by holding the furnace to temperature while the heavy ones are being heated uniformly through and up to temperature. This results in giving the lighter castings a longer soaking than necessary and greatly increases the amount of surface oxidation on them. The heat treatment on the charge as a whole has been nonuniform and gives results in conformity.

The method of charging the castings into the furnace and withdrawing them from the furnace will also have a bearing on the uniformity of the product. The better method, where a continuous furnace is not in use, is to put the whole charge in at one time instead of piece at a time and withdraw in the same manner. Where the castings are charged into a hot furnace one at a time they will be brought up to temperature at different periods of time instead of approximately at the same time, thus giving to the different castings a different period of soaking instead of a like treatment. When withdrawing from the furnace one at a time for air cooling or other cooling treatment, nonuniform conditions are obtained by reason of the different temperatures at which the castings will be taken from the furnace.

The matter of temperature measurement is one of the most vital connected with the proper heat treatment of steel. After having determined the temperatures required, the utmost care should be taken to secure these temperatures with accuracy day after day. Good pyrometers with proper recording charts should be installed so that the furnace operator can depend on their readings to follow instructions as to temperatures, and also furnish a check to the man in charge as to how closely instructions are being carried out. When the operator knows that a graphic record is being made at all times on his furnace operations, he is much more apt to be diligent in following out instructions.

After proper pyrometer installation has been made, it should not be forgotten or allowed to run along without frequent checking to determine if it is reading and recording correctly. There are several different methods for calibrating the thermocouples and indicating on recording instruments, and this should be done at regular intervals. A neglected or inaccurate pyrometer installation is worse than none at all, as it gives a sense of false security leading to erratic results. Thermocouples should be attached to the furnace in such a manner that the different parts of the heating chamber can be under observation for irregularity as to temperature. One thermocouple permanently located at one point in the furnace does not show the uniformity of temperature maintained in the heating chamber.

In the treatment of castings requiring quenching, the same degree of care should be taken in the quenching operation to secure proper results as is necessary in the process of heating. The quenching medium used, of course, is controlled by the result desired. If extreme hardness is desired, water or brine can be used, or if steel of lesser hardness is wanted, oil, heavy, medium or light. Having selected the quenching medium to suit the purpose for which it is intended, the actual operation of quenching should be carried out with extreme care as to details. The quenching medium itself or castings quenched, should be vigorously agitated in order to secure the full chilling effect of the medium, otherwise the liquid quench immediately surrounding the casting would become heated and correspondingly lose its efficiency for extracting heat from the metal, thus giving a slower cooling than calculated. Nonagitation will also cause gas pockets to form around and about the casting itself and bring about a process of unequal cooling, tending to cause warping of the casting.

As stated before, the matter of composition of material to be treated, heat treatment to be given, such as first temperature, drawing temperature, quenching medium, temperature at which quenched and temperature at which taken from quenching medium, are all questions to be determined by the individual plant conditions, but working along well defined principles

and according to certain data ascertained by extensive experience of others entitled to speak with authority. All the items carefully considered and worked out to form a standard of practice will, nevertheless, be of no avail unless the human element is taken into consideration. By this is meant the man or men who are selected to carry out the operations decided upon. No system, method or business is better than the man running it. In other words, it is hardly possible to devise a method of operation that is fool proof, so that it is quite essential to have the one in actual charge of operations a man of ambition and energy, one who wants to learn, wants to follow instructions, and one on whose word absolute reliance can be had. This last human asset obtained, results in conformity with calculations can be secured, and any failures can be traced to their true cause and additional knowledge gained from the failures.

SCALING OR OXIDATION AND REDUCTION OF METALS IN FUEL-FIRED FURNACES

By O. Lellep*

(A Paper Prepared for the Philadelphia Convention)

"The furnace atmosphere in our furnaces can be kept oxidizing or reducing as you like," said the salesman of the furnace company to the engineer of a steel plant, who was buying a furnace equipment for heat treatment of steel. "Our furnaces practically do not scale steel heated in them as ordinary furnaces do, because we keep the fuel and air automatically in the same proportion. We synchronize their flow. Our regulation can be set once for all time for a neutral or even slightly reducing atmosphere."

The buyer was convinced of the automatic synchronizing or proportioning of the fuel and air for its burning and understood as the practical language explicitly means a neutral furnace atmosphere is an atmosphere which does not oxidize nor reduce, that a reducing atmosphere reduces or transforms the oxide or scale into metal. He also believed that as the manufacturer actually could make and maintain the flame neutral or reducing, there should be no scaling at all.

Under good expectations the bargain was concluded, the order placed and the furnace erected. The disappointment of the plant engineer was great when in actual operation at a comparatively high temperature and long heating the furnace showed scaling.

Who is to be blamed? The buyer thought that he had had something "put over" by the salesman and accused the latter. The salesman told him what he believed and what under favorable conditions was true, but as mostly done in business he did not tell the real truth. Furthermore, the reason for this disappointment to a great extent lies in the incompleteness or incorrectness of the practical language which often uses the terms reducing flame and oxidizing flame. To avoid confusion let us define accurately the conceptions concerned. According to Webster a flame is "A stream of burning gas or vapor, emitting light and heat." Thus, an expressed quality of a flame is the burning or the reaction between fuel and oxygen. If this reaction is accomplished there is no flame any more but only a stream of highly heated gas which still can emit heat and light. A poorly constructed primitive gas burner delivering unmixed streams of gas and air into the furnace and also an

*Metallurgical engineer, Surface Combustion Co., New York.

oil burner actually give a flame according to Webster's dictionary. At these burners one can observe a pronounced zone of combustion. An efficient modern gas burner delivering theoretical homogeneous mixture and provided with means for localized quick combustion practically lacks phenomena of flame and is approaching flameless combustion especially at temperatures above 2000 degrees Fahr.. As a matter of fact, there is no such thing as generally reducing or generally oxidizing furnace atmosphere. A socalled reducing flame can be oxidizing and vice versa. To be clear let us consider some plain and simple experiments:

1. Suppose a small laboratory gas furnace is heated up to 1200 degrees Cent. with a correct homogeneous atmosphere containing a theoretical amount of air without excess gas and excess air—an atmosphere or flame which is called generally and also usually supposed to be neutral. Let us investigate its alleged neutrality. Into this furnace is placed a piece of magnesite brick with two cavities. One cavity contains a piece of steel needle and the other cavity a grain of cuprous oxide. After a while the steel is oxidized entirely and transformed into scale while the cuprous oxide is reduced into a rounded molten button of metal. Thus it is plain that a furnace atmosphere with a theoretical amount of air at 1200 degrees Cent. actually gives an atmosphere which reduces cuprous oxide into metal but under the same conditions oxidizes iron. Therefore, one can speak only of an oxidizing, reducing or neutral atmosphere for a certain metal or substance.

2. Let us consider any laboratory gas furnace which easily gives a high and controllable temperature as for instance the surface or flameless combustion furnace invented by Professors Lucky and Bone or a Meker furnace. Let the furnace atmosphere contain some small amount of excess oxygen, say 2 per cent and the furnace have a temperature of 1000 degrees Cent. Under these conditions a piece of metallic copper wire about 1-64 inches in diameter placed upon a piece of magnesite brick into this furnace will be oxidized entirely. Now let us raise the temperature of the furnace with a flame having the same amount of excess oxygen to 1700 degrees Cent. and place into the furnace upon a cupel a grain of cuprous oxide. After a while it will be reduced into metallic copper although the flame does not contain any reducing gas but contains a small amount of free oxygen. This experiment shows that besides the composition of the flame, a change in temperature can change the reducing or oxidizing qualities.

3. That a furnace atmosphere with a correct amount of air without free oxygen and without unburned gas, a socalled neutral flame, gives an oxidizing atmosphere for steel was shown by the first experiment. Let us heat our furnace in this third experiment with a rich flame containing unburned gas, for instance 7 per cent $CO + 2H$, which flame is generally but incorrectly called reducing. Let our heat treatment furnace have a temperature of 800 degrees Cent. and our steel needle be in the atmosphere of this flame. After an hour of heat treatment, one can observe a very thin layer of scale although the needle was plunged into oil in the furnace itself and thus any oxidization during the cooling period prevented. • The thickness of metal destroyed by oxidation amounts to practically nothing—approximately 0.0005-inch—but undoubtedly the atmosphere, although it contained a considerable amount of excess gas, was oxidizing. If we were to try the effect of a flame with some small amount of excess gas at 1300 degrees Cent. we would notice that the

atmosphere remains oxidizing for steel.   Thus a certain atmosphere can not only be oxidizing for steel and reducing for copper at the same time (1st experiment); but an atmosphere of a definite composition can be oxidizing for a metal at 1000 degrees Cent. and it can be reducing for this metal at 1700 degrees Cent. (2nd experiment).   Further a furnace with a hearth open to fire gases remains more or less oxidizing or scaling for steel under all practical conditions in heat treatment furnaces (3rd experiment).

Thus it would appear that there exists an anarchy in the oxidizing and reducing conditions of an atmosphere for metals.   That is only apparent for physical chemistry has given certain laws, which predict when a furnace will oxidize and when it will reduce.   Whether a metal oxide will be reduced or a metal oxidized into scale depends only on the oxygen pressure and on the temperature around the substance.   A metal oxide is reduced when the oxygen pressure of its decomposing oxide is higher than the oxygen pressure of the surrounding atmosphere, and a metal is oxidized when the oxygen pressure of its oxide under thermal dissociation is lower than the oxygen pressure in its surrounding atmosphere.   It is comparatively easy to measure the temperature but much more difficult to measure the oxygen pressure at the thermal dissociation of metal oxides, which varies from several atmospheres for silver oxide to several thousandths of a millimeter mercury for iron.   In the furnace atmosphere the partial pressure of oxygen must be considered. Partial pressure of oxygen in air is about 1/5 atmosphere or 760/5=152 millimeters of mercury.   In a furnace gas resulting from burning fuel with 100 per cent excess air, it is half of this amount.

If fuel is burned with a theoretical amount of air in the furnace gases, the oxygen pressure approaches zero and measures in fractions of a millimeter of mercury, owing to some thermal dissociation of water vapor and carbon dioxide.   In a rich furnace atmosphere with some excess fuel, incorrectly called a reducing flame, this oxygen pressure might measure in microns of mercury gage, but it exists and determines the all important conditions for reduction and oxidation of metals.   Returning to the practical combustion gases and considering them from the viewpoint of reduction and oxidation, one can conceive that it does not pay to make the atmosphere in an open-flame fuel-fired furnace actually reducing for steel.   But it could be made by some complicated means either by increasing the percentage of unburned gases and thus diminishing the amount of dissociated oxygen or by increasing the temperature.

In flames where fuel is burned not with air but with oxygen, for instance the oxycetylene flame, the conditions are much more flexible. In those flames the unnecessary ballast, atmospheric nitrogen which accompanies oxygen in four parts to one part is not present.' Therefore, an oxygen flame gives a very high temperature so high that it is difficult to measure it.   The oxygen pressure of dissociated oxides increases rapidly with temperature and therefore it is a comparatively easy matter to reduce actually with a very hot oxyacetylene flame iron oxides into metallic iron.   The reduction of iron ore in a blast furnace also is due to a high temperature in presence of free carbon.   An actually reducing condition for steel exists also in closed vessels as in carbonizing boxes in presence of free carbon, but ordinary steel heat treatment as hardening, forging and annealing furnaces remain slightly oxidizing or scaling

disregarding the unjustified and contradictory claims. A rich furnace atmosphere containing a large excess of fuel or falsely called reducing atmosphere remains actually slightly oxidizing for steel at these temperatures. Likewise the atmosphere of a muffle furnace, consisting of products of combustion or air is oxidizing for steel.

For the purpose of diminishing scaling effect it can be recommended:

1. To exclude free oxygen from furnace gases by using modern furnaces. There are on the market at present time well developed and very satisfactory automatic gas and air proportioning devices of different makes. For a gas furnace particularly, there is no excuse for free oxygen in furnace gases. The old assumption that some excess air was necessary for a complete and efficient combustion in gas furnaces is not true. A thorough mixing of air and gas before entering into the furnace helps much towards a complete and quick combustion. Localized combustion on baffle walls, impinging refractory beds and a combustion tunnel have the same effect.

2. To protect the steel from direct contact with the flame or to stay where the velocity of the furnace gases on the surface of steel is as low as possible.

3. In many forging and other heat treatment furnaces, the scaling is effected not so much in the furnace as outside of it during forging, pressing or moving from one place to another. This cause of scaling can be diminished by shortening the necessary time of exposure to a minimum.

The scaling of steel in furnaces is due to two causes: The presence of free oxygen in furnace gases; and the oxidization effect of carbon dioxide and water vapor. The first cause, free oxygen, can be eliminated entirely in a modern gas furnace by automatic gas and air proportioning devices. The second cause affects steel very slowing and for shorter heating operations below $\frac{1}{2}$ hour practically is negligible.

The terms reducing or oxidizing atmosphere in furnaces or reducing or oxidizing flame are misleading or incongruous as there is no reducing or oxidizing condition in general but only relative reduction or oxidation of certain substances at a determined temperature and composition by the surrounding furnace atmosphere. It seems more practical, therefore, to state, instead of the misused reducing and oxidizing flame, a rich and lean flame; the first term defining a flame with more than the theoretical amount of fuel, the second term a flame with less than the theoretical amount of fuel.

News of the Chapters

NEW CHAPTER IN CHARLESTON

The first chapter of the American Society for Steel Treating to be organized by others than the National office was instituted in Charleston, W. Va., on the first of February. The application for the Charleston chapter was granted by the Board of Directors of the National Society late in December, upon the petition of some 17 interested men.

At the organization meeting of the chapter, Mr. H. Schagrin, chief chemist of the U. S. Naval Ordnance Plant, was elected chairman, and Mr. W. I. McInerney, foreman of heat treating at the armor plant of the U. S. Navy,

Harry Shagrin,
Chairman Charleston Chapter

was elected secretary-treasurer. The first stated meeting was held on Feb. 1st when 65 members were in attendance. A very interesting paper was presented by Mr. C. E. Margerum, metallurgist of the U. S. Navy Ordnance Plant, upon the subject of "Mechanism of Heat Treating." At the close of Mr. Margerum's paper, a very lively discussion was held, besides various matters of importance were also discussed.

The next meeting will be held March 1st when Mr. D. M. Giltinan foreman of heat treating of guns and shells will present a paper on "Pyrometry."

The spirit and enthusiasm manifested by the officers and members portends a most successful career for the Charleston chapter.

Major F. H. Schoenfuss,
Vice Chairman, Charleston Chapter

W. I. McInerney,
Secretary-Treasurer, Charleston Chapter

THE PRESIDENT'S VISITS

Lt. Col. A. E. White, professor of engineering research, University of Michigan, and national president of the American Society for Steel Treating, completed his inspection of the Eastern chapters on Feb. 18. The chapters were visited in the order given:

Monday, Feb. 7—Boston
Tuesday, Feb. 8—New Haven
Wednesday, Feb. 9—Bridgeport
Thursday, Feb. 10—Hartford
Friday, Feb. 11—Springfield
Monday, Feb. 14—Providence
Tuesday, Feb. 15—New York
Wednesday, Feb. 16—Philadelphia
Thursday, Feb. 17—Baltimore
Friday, Feb. 18—Washington

At all of these chapters, special arrangements were made to entertain the national president, and a large turn out greeted him in every chapter. The stimulating effect of his visit was most pronounced, and he added many friends to his already large list of acquaintances.

CHICAGO CHAPTER

The Chicago chapter held its February meeting on Feb. 14 in the Lumbermen's Exchange building, at which time over 150 were present. Mr. Lowry, metallurgist for the Oliver Chilled Plow Works, South Bend, Ind., presented a very interesting paper on "Practical Malleable Anneal-

ing." Mr. Lowry has given many years study to the subject, and his paper proved particularly valuable to the producers and users of malleable castings. The second speaker of the evening was C. P. Berg, consulting industrial engineer of Chicago, whose paper on the "Relation of Heat Treatment to Factory Production" was very enlightening and particularly interesting to the executives of plants.

An interesting and well prepared letter sent out to the executives of plants by F. C. Lau, chairman of the Chicago chapter, was productive of excellent results in boosting attendance. Mr. Lau's letter follows:

January 25, 1921.

Dear Sir:

"We respectfully invite your attention to our organization which has for its purpose the advancement of the art of heat treating of metals and the placing of the industry on a more scientific basis. This fact has prompted our executive committee to try and co-operate with the heads of Manufacturing Plants as to the best procedure that will show results at the factory.

"INDUSTRIAL EXECUTIVES NIGHT, Monday, February 14th, at the Lumbermen's Association Club Rooms, 4th Floor, 11 South La Salle Street, will afford the opportunity. You will not be lonesome as over a hundred of Chicago's leading industrial executives have been invited. Dinner at 6:30, $1.50 per plate. Meeting starts at 7:30. If you cannot participate in the dinner, come at 7:30.

"Mr. Lowry, Metallurgist for the Oliver Chilled Plow Works, of South Bend, Ind., will address us on the subject of "Practical Malleable Annealing".

"After a limited discussion of this subject, Mr. C. P. Berg, Consulting Industrial Engineer of Chicago, will talk upon the "Relation of Heat Treatment to Factory Production".

"The merits of the AMERICAN SOCIETY FOR STEEL TREATING must be judged by results shown in quality and quantity of output in your heat treating departments.

"Your presence with some of your shop men that night will be well worth while. An apportunity to let men from the shop rub elbows with men from other shops who are encountering the same difficulties and overcoming them, will, we are sure, make them worth more to you.

"If you will kindly fill out the enclosed blank with the names of those you think are interested and whom you want to attend, we will be glad to make reservations for them.

Yours very truly,

F. C. LAU, Chairman."

PHILADELPHIA CHAPTER

About 100 members attended the meeting at the Engineers Club on Jan. 28. The principal paper of the evening was delivered by H. M. Brayton, research engineer of U. S. Ordnance Corp., on the subject of "Heat Treatment of Ordnance". At the close of Mr. Brayton's very interesting paper, Mr. G. Oertson, president of the Engineers Club gave some very interesting data on "Heat Treatment of Guns, by Midvale, for the U. S. Navy, in 1876." Mr. Bullens, consulting metallurgist, Royersford, Pa., and author of the text book "Steel and Its Heat Treatment", gave a short talk on the "Fundamentals of Heat Treatment with Special Reference to Critical Ranges".

The membership campaign has been especially successful and the total membership of the chapter at present is 226, and still growing. H. J. Huester received first prize of $10.00 for having secured the largest number of new members. A peculiar coincidence of this feature was that the number of new members he secured was 13. There was a triple tie for second prize, E. G. Gaughan, G. W. Tall, and G. P. Bible, each having 8 new members to their credit. Mr. Tall and Mr. Bible

withdrew in favor of Mr. Gaughan, and the second prize of $5.00 was awarded to him.

The Philadelphia chapter had the largest meeting since it has been organized on Wednesday evening, Feb. 16 at the Engineers' Club. This meeting was held in honor of the official visit of the national president, Lt. Col. A. E. White, and to make the meeting irresistible, the following distinguished guests were invited to attend and speak at the meeting: Dr. George K. Burgess, chief of metallurgical division, Bureau of Standards, Washington; Morris E. Leeds, president of Leeds & Northrup, Philadelphia; Prof. Jos. W. Richards, professor of metallurgy, Lehigh University, and Richard Spillane, business editor, *Philadelphia Public Ledger*.

Dr. John A. Mathews, president of Crucible Steel Co. of America, had planned to be present, but at last found it impossible to attend. However, he sent the following telegram which was read at the meeting:

"I regret exceedingly that urgent business keeps me in Pittsburgh today. I especially desired to pay my respects to Lt. Col. White in appreciation of the splendid work he performed in merging the two societies, and is now doing as president of the United society.   J. A. MATHEWS."

SCHENECTADY CHAPTER

The Schenectady chapter had a rather novel and interesting meeting in which they mixed music and magic with the black art of heat treating. The meeting was held in the Civil Engineering building, Union College, on Monday evening, Feb. 7. The principal paper was presented by E. F. Collins, consulting engineer industrial heating devices, General Electric Co., on the subject of "Relative Thermal Economy of Electric and Fuel Fired Furnaces, and Its Influence on Process Costs and Plant Efficiency." Mr. Ippolito, Union College entertained with piano selections, and Mr. Correa of Union College, with feats of magic. A very lively discussion was held at the close of the meeting when the metallurgical troubles of all present were brought up and given consideration.

WASHINGTON CHAPTER

H. J. French, physicist of the Bureau of Standards has been elected secretary-treasurer of the Washington chapter. Mr. French is a very capable young man and the chapter looks forward to increased activities.

CLEVELAND CHAPTER

The January meeting was held in the Cleveland Engineering Society rooms at the Statler Hotel, on Jan. 21. Dr. S. L. Hoyt, metallurgical engineer of the experimental engineering laboratories of the National Lamp Works, Cleveland, presented a paper on "Impact Properties of Metals and Notch Tests." Dr. Hoyt has done a great amount of work on this subject and presented to the members first hand information. Over 70 were present for the dinner and attended the meeting.

Cleveland chapter had a very interesting meeting, at the Hotel Statler on Friday evening, Feb. 25, when the speaker was Dr. George K. Burgess, chief of the division of metallurgy of the United States bureau of standards, Washington, who presented a paper on the "Metallurgical Work of the United States Bureau of Standards." Invitations were extended to the

members of the Cleveland Engineering Society, as well as the Cleveland branches of the American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, and Society of Automotive Engineers. Altogether, about 350 were present.

DETROIT CHAPTER

The January meeting was held in the Board of Commerce rooms on Jan. 27. A. F. McFarland, metallurgical engineer of the Vanadium Alloys Steel Co., Pittsburgh, presented an interesting paper on "Some Notes on the Heat Treatment and Structural Characteristics of High Speed Steel." Mr. McFarland is an authority on high speed steel and his paper offered conclusive evidence that he had given his subject very careful and thorough consideration. An interesting and lively discussion followed the presentation of the paper.

LEHIGH VALLEY CHAPTER

The February meeting was held in the Bethlehem club, Bethlehem, Pa., on Feb. 7, at 8 p. m. The address was given by W. S. Landis on the subject, "Electric Furnace and Future Geography of the Steel Industry." The meeting was a rousing success and every one felt well repaid for having been present to hear Mr. Landis.

BRIDGEPORT CHAPTER

C. W. Copeland who has served very efficiently as secretary-treasurer of the Bridgeport chapter since its organization, has relinquished his duties in this capacity as well as those of metallurgist for Hares Motors Inc., and has accepted a position as metallurgist with the Timken Roller Bearing Co., Detroit.

The Bridgeport chapter was very fortunate in securing for their new secretary, Mr. Charles F. Schmelz, superintendent of Curtis & Curtis Co. Mr. Schmelz is not unfamiliar with the details of his new position as he has served very capably as a member of the executive committee of the Bridgeport chapter.

NORTH WEST CHAPTER

Eighty members of the North West chapter attended one of the most interesting meetings this chapter has held, when G. A. Richardson, of the Midvale Steel & Ordnance Co., presented a paper on the "Production of Tool Steels", illustrated by lantern slides. The meeting was held in the rooms of the Manufacturers' Club.

NEW YORK CHAPTER

A very lively meeting was held in the Machinery Club, 50 Church St., on Jan. 19. About 100 were in attendance to hear E. F. Davis of the Celite Products Co., who gave an interesting talk on the subject of "Function of Insulation and Its Application to Heat Treating Furnaces."

SYRACUSE CHAPTER

The Syracuse chapter had an interesting meeting on Jan. 27 at the Technology Club. Ninety members and guests were in attendance. A. M. Reeding of the Leeds & Northrup Co., presented a very instructive

paper on "Pyrometers and Their Application to the Heat Treatment of Steel". The discussion was lively at the close of the paper and was participated in by a large number of those present.

MILWAUKEE CHAPTER

The Milwaukee chapter held its February meeting on Feb. 18 at the Continuation School when about 75 listened to Prof. J. F. Keller present his illustrated lecture, "Steel and Its Selection". The meeting was pronounced an excellent one by all present, and a very interesting and complete discussion followed the presentation of the lecture. The meeting was preceded by a dinner at the Medford Hotel.

ST. LOUIS CHAPTER

St. Louis chapter had a very interesting and instructive meeting on Jan. 26 at the American Hotel. Richard P. Brown, president of the Brown Instrument Co., presented an excellent paper on "Pyrometry, Its Past, Present and Future, in Conjunction with the Heat Treatment of Steel". The paper was of such a character as to present unusual interest to the members. The meeting was preceded by a dinner which was largely attended.

A very interesting meeting of the St. Louis chapter was held in the City Club at St. Louis on Friday evening, Feb. 25. H. Belleville, vice president of the Commonwealth Steel Co., entertained the members with three reels of motion pictures, entitled, "For the Good of the Commonwealth". Mr. Belleville explained the pictures as they were shown and answered questions asked. The bureau of mines had pronounced the reel showing the melting in the open-hearth furnace a revelation and epoc in metallurgical photography. The meeting was preceded by a dinner.

PITTSBURGH CHAPTER

An exceedingly interesting discussion followed the presentation of Carl Oehler's paper on the "Essential Features of Electric Furnace and Its Future in the Iron and Steel Production," which was presented at Pittsburgh, in the Chatham Hotel, on Jan. 18. Seventy five members of the society were in attendance.

The Pittsburgh chapter had its February meeting on Feb. 15, at the Chatham Hotel, when W. L. Patterson of the Bausch & Lomb Optical Co., Rochester, N. Y., presented a very interesting illustrated paper on the subject of "Optics of Metallography". Over 75 were in attendance and participated in the discussion following the presentation of the paper.

CINCINNATI CHAPTER

R. A. Mitchell of the Pollak Steel Co., addressed the chapter on "Forging Practice", at the January meeting of the Cincinnati chapter, on Jan. 14. The meeting was held at the Ohio Mechanics' Institute and was attended by 65 members and guests. At the close of the meeting, a buffet luncheon was served which added to the occasion.

The Cincinnati chapter held its February meeting on Feb. 18 at the Ohio Mechanics' Institute. R. M. Taylor, of the American Tool Works Co., presented a paper on "Steels for Machine Parts". About 45 members were present at the meeting. A buffet luncheon was served at the close of the meeting.

AMERICAN SOCIETY FOR STEEL TREATING.
Hartford Chapter

PROGRAMME
1920 – 1921

PRACTICAL DEVELOPMENT OF STEEL FROM ORE TO TREATER	DISCUSSION OF ELEMENTS AND TREATMENT	BALANCE OF TIME
Nov. 11, Ore - Coke	Phosphorous & Sulphur	
Dec. 9, Fundamental Chemistry	Manganese & Spiegle	Are's and "Aints"
Jan. 13, Blast Furnace	Carbon & Silicon	Terminology
Feb. 10, Wrought Iron	Nickel	
Mar. 10, Bessemer	Chromium	
Apr. 14, Open Hearth	Vanadium	Special Papers
May. 12, Crucible & Electric	Tungsten	To be announced
June 9, Fabrication	Molybdenum, Titanium, Cobalt	

"DON'T BE A SPONGE, BUT IF YOU MUST, ONCE IN A WHILE GIVE YOURSELF A SQUEEZE."

D.H.STACKS Chairman   M.E.GERE Vice Chairman   C.T.HEWITT Sec.&Tres.

COMMITTEES

EXECUTIVE	PROGRAM	FINANCE	ENTERTAINMENT	MEMBERSHIP
OFFICERS	M.E.GERE Chairman	C.T.HEWITT Chairman	J.F.WADE JR. Chairman	A.H.DARCAMBLE Chairman
G.P.MOORE A.H.DARCANBAL	G.P.MOORE	D.H.STACKS	S.P.ROCKWELL C.M.BLACKMAN R.C.BALDWIN ViceCar.	
F.P.GILLIGAN E.M.WHITING	L.A.LANNING	E.M.WHITING	W.R.BENNETT F.B.COYLE	
J.F.WADE JR. R.C.BALDWIN				

Commercial Items of Interest

A statement made recently reports the work of the committee on heat treatment of carbon steel of the engineering division of the National Research Council.   For these investigations, steel specimens are provided by John A. Roebling's Sons Co., and rolled into round bars by the Carpenter Steel Co.   Heat treatments and some of the microscopic examinations are conducted in the private laboratory of Dr. Henry M. Howe, chairman of the committee, who has devoted a greater part of his time during the last 15 months and without pay.   Microscopic examinations are made at the University of Minnesota while magnetic tests are made at the bureau of standards.   During the year ending June 30, 1920, the bureau of standards and bureau of mines furnished $10,000, but because of curtailment of congressional appropriations, their contribution for the current year was reduced to $3500.   The test pieces are being machined by the bureau of mines at Pittsburgh, the Bethlehem Steel Co., the General Motors Corp., the Neverslip Co., and the American Tool & Machine Co., without charge.   Mechanical tests are being conducted at the bureau of standards and the Watertown arsenal.

For the inspection of steel rails, rods, wire, cable, and all other steel and iron stock of uniform section, the Burrows deflectoscope and magnetic analyzer is described in bulletin No. 41 recently distributed by Holz & Co., Inc., 17 Madison avenue, New York.   A history of magnetic analysis in the United States, fundamental magnetic quantities and magnetic analysis are discussed in the first eight pages.   The balance of the 20 pages is devoted to details of the apparatus, its operation and applications.   Photographs and charts are used in illustration.

Bulletin No. 11, distributed by Holz & Co., Inc., 17 Madison avenue, New York, describes the Eden-Foster repeated impact testing machine developed for investigating the resistance of steel and other metals to fatigue produced by repeated stresses of small force.   Several illustrations and tables give the specifications of the machine.

According to recent information from the industrial heating section, supply department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., considerable experimentation has been done during the past year, and much progress made in the development of a reliable and satisfactory high-temperature heat treating furnace, with the result that there are now available electric furnaces for working temperature up to 1800 degrees Fahr. and up to 2000 degrees Fahr. in some special cases.   The following installations made will show some of the results accomplished, and the relative value of this type of furnace.

A 120-kilowatt furnace has been in operation for over a year heat treating automobile springs.   The furnace is operated at 1560 degrees Fahr.   Two tests made at different intervals showed consumptions of

1520 kilowatt hours for 15,000 pounds of springs and 1550 kilowatt hours for 16,330 pounds of springs treated. Initial temperature of the steel was 70 degrees Fahr, and weight of the charge 675 pounds.

Due to the fact that no combustible gases are generated in the electric furnace, no stacks are required, therefore, the efficiency is high. Likewise, there is no escaping gas, no odor, no smoke from the electric furnace. At an installation made in a tool room, it was found necessary to install steam radiators in the room for the comfort of the employes, who had difficulty in keeping cool when operating the fuel-fired furnaces even during the coldest weather.

For the manufacture of all types of coil springs from wire up to ½-inch diameter, the Superior Spring Co. recently has been incorporated at Springfield, O. Automatic equipment has been installed and on March 1, production was commenced under the supervision of Joseph H. Sullivan, who has had 25 years experience in the manufacture of coil springs. Special attention will be given to the production of porch swing springs.

"Research and Methods of Analysis of Iron and Steel," is the title of a 220-page book issued by the American Rolling Mill Co., Middletown, O., describing and giving the history and chemical analysis of a number of ancient irons. Considerable data on the subject of · research on corrosion is presented which deals particularly with the gas content of iron and steel and with the influence of various gases upon the rate of corrosion. Several views of the apparatus used for magnetic testing are shown, including those used for determining the permeability value, the core loss and the aging coefficient. The section entitled "Metallurgical Control" deals with scientific heat treatment, thermoelectric and optical pyrometers, microscopic tests and physical tests including methods for determining tensile strength, hardness, ductility and alternating stress.

The Chicago Coil Spring Co., Chicago, has under construction an addition to its plant. The structure will add about 18,000 square feet of space. This will be devoted to manufacturing upholstering springs, furniture and automobile couch constructions, japanning ovens and steel treating furnaces. It will be equipped with a full line of spring making machinery.

Oscar A. Michel, American and foreign patent, trade mark, design and copyright attorney, 324 International Life building, St. Louis, Mo., recently has opened a branch office in Washington, where a representative will render service in any matters relating to patents, trade marks, designs or copyrights.

The Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., recently has been named exclusive agents in the United States and Canada for the line of industrial type electric furnaces manufactured by the Electric Heating Apparatus Co., Newark, N. J. The standard heavy-duty industrial furnaces include 12 different sizes from 18 inches wide, 24 inches long and 13½ inches high, inside dimensions, with a capacity of 22 kilowatts up to 32 inches wide, 72 inches long and 16 inches high with a capacity of 80 kilowatts. Either automatic or manual temperature control is supplied with the furnaces.

arch

urs
was

ec-
ke-
ur-
to
res,
ces

nch
ng-
cion
had
will

f a
O.,
of
n is
and
eral
ose
co-
tific
and
ess,

ad-
pace.
and
ces.

and
Mo.,
nta-
rks,

ently
the
eat-
fur-
13½
32
kilo-
the